The Cost Of A Crazy Idea

ONLY TOO OFTEN the cost of a "crazy" idea is the money that is lost by not adopting it. But usually one can not calculate the money lost by failing to progress and hence the loser is rarely aware of his loss. Thus he continues on through life, blissfully ignorant of the many sweet damsels of opportunity who had knocked at his door only to be rebuffed by a gruff, "Go on, you're crazy."

To be sure, where ignorance is bliss, 'tis folly to be wise. But 'tis wiser not to be blissfully ignorant. We give our own "crazy" ideas plenty of attention but when the same "crazy" idea is broached by someone else we are inclined to give it scant notice. Too often other pressing matters are demanding attention and the clock hands are swiftly approaching quitting time. Perhaps the proposer of the "crazy" idea has made a poor presentation. People with inventive minds usually do, for they are not salesmen, but inventors.

It is too irking to listen to an enthusiastic, though usually jumbled, description about something one does not understand. And as all executives know, it is so easy to stop it all and "get back to work" by simply saying, "We're not interested, there are so many other more important problems for us to solve."

Thus, discourteously, is the budding genius pushed back into his bud and the boss pats himself on the back for having disposed of the matter promptly and efficiently.

Fortunately for the progress of the world there are "bosses" and executives who listen attentively to all new ideas, crazy or otherwise, who investigate them thoroughly and appraise them from every angle. Were it not so this world would still have a few centuries to go before it could reach its present stage of material development. And great is the reward for listening to a "crazy" idea that "goes across." One success offsets dozens of failures.

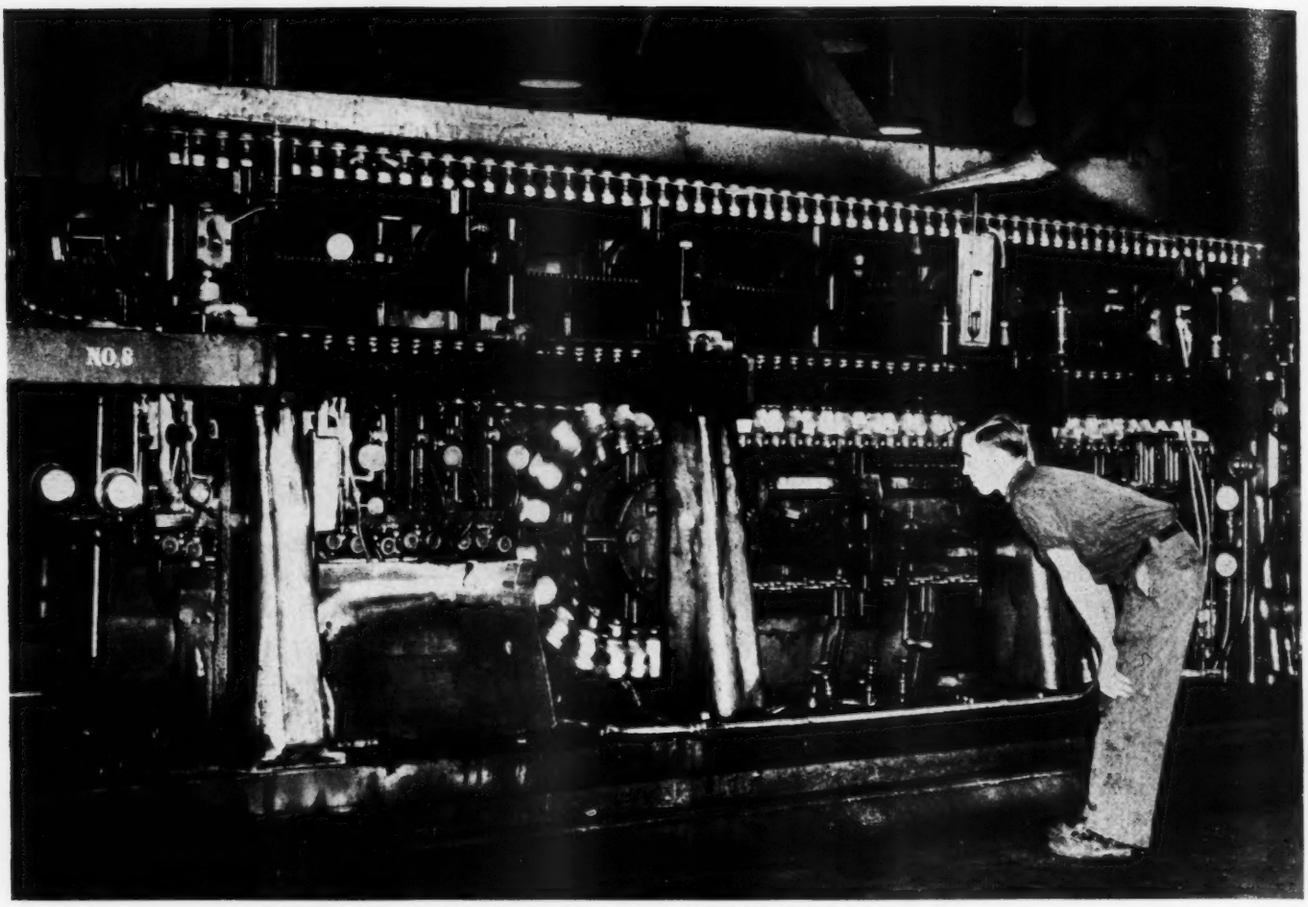
Turning back the pages of history, we read that Gallileo was flogged to force him to recant his statement that the earth moved around the sun. Pasteur was ostracized from the medical profession because he claimed that diseases were caused by germs. Charles Goodyear was laughed at. People swarmed to the banks of the Hudson River for the opportunity to deride Fulton upon the expected failure of his steamboat.

Of course, one might think that such things could not happen today. People are too intelligent. But a number of incidents come to mind. An inventive draftsman proposed a fundamental change in the design of tanks. His boss laughed at the idea and the young man quit, chagrined and disgusted. He happened to mention his idea in a casual manner to his new boss in a competing company. The idea was quickly developed and patented. The first company is now paying royalties to the second company and the draftsman shares in the profits.

Not many years ago the superintendent of a now defunct company proposed the design and manufacture of all-steel automobile bodies to be assembled by resistance welding. He was laughed at and quit, started a small business to carry out his ideas, went practically broke because of lack of capital, but finally succeeded and is now the principal owner and president of the company that bears his name—The Edward G. Budd Manufacturing Company. Perhaps it is significant that the company that refused to entertain Edward G. Budd's ideas is no longer in business.

Numerous other similar instances could be cited; most engineers know of several. The cost of a "crazy" idea is not always the cost of trying it and having it fail. Too often the cost is that of turning it down and having someone else adopt it and make huge profits from it. Missing one profitable "crazy" idea may mean missing more in profit than would be lost on dozens of truly unsound ideas.

Judgment on a new idea should not be made until the idea has been fully investigated from every angle.



Machine blows 400 to 600 lamp bulb blanks per minute from a thin belt of molten glass

GLASS FOR MECHANICAL PARTS

Product Design Possibilities and Physical Properties

T. J. THOMPSON, *Manager*
Corning Glass Works Industrial Division

PRESENT DAY applications of glass are commonplace yet thought is seldom given to the importance of the contributions made by this useful material to modern living. Glass is one of the most ancient of materials effectively used by man. The history of glass making goes back at least 3,000 years.

Although there are thousands of different glass compositions, each painstakingly evolved for some specific application, the presence of silica in varying percentages is common to all. The majority of glasses in common use, however, fall into one of three major classifications: "Lime," "Lead," and "Borosilicate" glasses.

Lime glass is a mixture of lime (CaO), silica (SiO_2) and, usually, small quantities of sodium or potassium oxides. This is by far the most widely employed basic composition, applications for which are found in window glass, bottles, tumblers, tableware, light bulbs, and illuminating fixtures. Lime glass is characterized by low cost, high thermal expansion, and good "glass working" properties.

Lead glass, in addition to silica, carries lead oxide up to 60 per cent by weight, some minor constituents are also incorporated to impart special characteristics. Lead glass is characterized by a high index of refraction from which is derived the attractive sparkle and luster so desirable in decorative cut glass or engraved glassware. In the form of tubing, the electrical and sealing properties of lead glass find extensive application as the internal stems of electric light bulbs which carry the filament supports.

Borosilicate glass, as the name implies, consists almost entirely of the oxides of boron and silicon. Most important of the properties of borosilicate glass is its extremely low thermal ex-

pansion of 0.0000018 in. per in. per deg. F. This coefficient of expansion is approximately one-third to one-fourth that of most metals and that of the cheaper lime glasses, and accounts for the marked heat resistance of borosilicate glass and its unique ability to resist thermal shocks that would instantly shatter other glasses. The outstanding stability of this composition in the presence of powerful acids and alkalis, is taken advantage of in the chemical process industries in the form of piping, centrifugal pumps, tubing, laboratory ware, and special equipment.

The non-crystalline structure of glass probably accounts for the notable absence of fatigue when subjected to repeated loading within design limits. The glass spring, shown in Fig. 1, is designed to exert a force of approximately one lb. at 3/32 in. deflection in a corrosive sulphuric acid atmosphere. After many million deflection cycles the spring showed no evidence of failure.

In addition to heat resistance and chemical stability, borosilicate glass has a number of other properties which make it particularly adaptable for mechanical and electrical design purposes.

Some physical constants of a borosilicate glass of the type used in "Pyrex" piping are:

Linear coefficient of expansion—0.0000018 per deg. F. between 66 to 660 deg. F. (19 to 350 deg. C.).

Modulus of elasticity—9.8 $\times$ 10^6 lb. per sq. in., or 6,900 Kg. per sq. mm.

Specific gravity—2.23

Specific heat—0.20

Refractive index—1.474

Thermal conductivity—8.1 B.t.u. per sq. ft. per hr. per in. thk. per deg. F. at 77 deg. F.

Dielectric strength in air—3,200 kv. per in. at 1/8 in. thickness

Volume resistivity—4 $\times$ 10^{14} ohms per cu. in. at room temperature

Surface resistivity: at 34 per cent humidity—10^{14} ohms per sq. in.; at 85 per cent humidity—14 $\times$ 10^9 ohms per sq. in.

Abrasion resistance—About twice that of plate glass.

Compared with metals, glass in general has low density and great electrical resistivity. Thermal conductivity is low, but in spite of this, substantial overall rates of heat transfer are obtained with tubular glass heat exchangers in the process industries by using strong thin walled tubes. In many such applications the fluid films on both sides of the glass tube rather than the tubes proper comprise principal resistance to heat flow.

Borosilicate glassware is transparent to certain wave-bands of thermal radiation and this characteristic often compensates for low thermal conductivity, so that relatively high rates of heat transfer are obtainable through high temperature radiation from flame or electrical resistance elements in conjunction with properly designed and processed glassware. Familiar applications are "Flameware" cooking vessels of "Pyrex" brand composition.

Low coefficients of friction are attainable with glass, probably as a result of hardness and extreme smoothness of polished surfaces. Here again the non-crystalline structure of glass may be responsible. With an ordinary commercial lubricant between two optically flat glass plates, the coefficient of static friction was recently found to be approximately 0.006 when subjected to loads up to 10,000 lb. per sq. in. The field for glass as bearings naturally suggests itself, but in bearing applications, special consideration must be given to heat dissipation because of the relatively low thermal conductivity of glass.

Borosilicate glassware of the type employed in "Pyrex" brand ware has an ultimate tensile strength of 6,000 to 10,000 lb. per sq. in. Much of the strength of glass is, however, dependent on the condition of the surface. For most engineering design calculations a maximum permissible tensile stress of 1,000 lb. per sq. in. is employed, thus insuring an adequate factor of safety. This value applies to annealed glassware; for "processed" or "tempered" glassware, a maximum working tensile stress of 2,000 lb. per sq. in. or more is permissible.

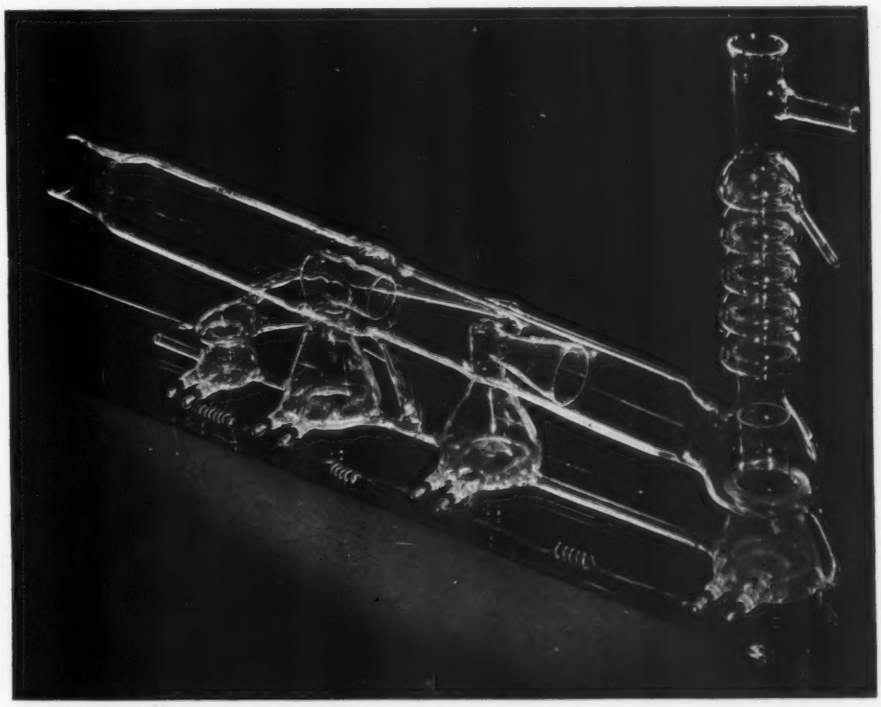
The compressive strength of glass is above 100,000 lb. per sq. in. Advantage is taken of the high compressive strength of glassware by tempering processes

Fig. 1—Glass springs 1½ in. diam. which exert a force of one lb. at 3/32 in. deflection

which induce permanently high compression stresses in the surface layers by controlled chilling methods; consequently, applied tensile forces must first overcome surface compression stresses before becoming operative as tensile loads, therefore, the "tempered" glassware is effectively strengthened against tension. Also, these surface compression layers greatly reduce the weakening effect of small surface scratches.

The tools and many methods employed by the artisan who blows and shapes high-priced decorative ware are practically identical with those of 2,000 years ago. In the interim, of course, equipment and methods have been developed

Fig. 2—Vacuum pump, hand fabricated mainly from machine-drawn glass tubing as the constructional material

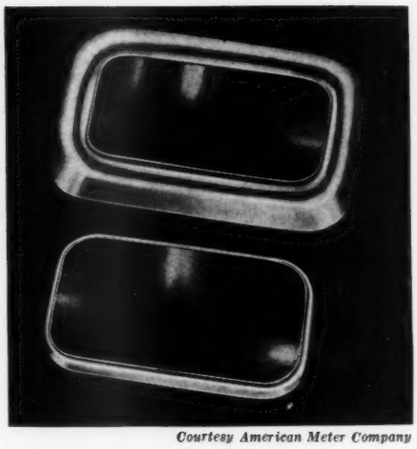


for automatic machine production of pressed ware, tubing, lamp bulbs and other blown ware, which have made possible the low prices of much commercially important glassware. Intermediate between the oldest and modern production methods are the numerous combinations of hand and machine operations required for manufacture of specialty glassware in quantities too small to justify or of a design not adaptable to automatic production; in either event the manual skill of the artisan usually can be supplemented by machine operations to produce ware at reasonable cost.

An impressive example of high speed automatic production of glassware is the manufacture of lamp bulb blanks on the "Corning" machine which blows them from a thin belt of molten glass at a rate of 400 to 600 bulbs per min. Contrasted with this is a glass vacuum pump designed by Distillation Products Co., shown in Fig. 2, which has experimentally attained pressures of less than 10^{-8} mm. of mercury.

Except for lenses and optical ware generally, it has not been economically feasible until recently to supply glassware to the narrow dimensional tolerances which have long been specified for metals. Fortunately, the majority of glassware does not require adherence to close dimensional specification. However, along with the major developments which have resulted in lower production costs, there have been parallel advances in dimensional accuracy. In fact, ability to produce glassware to narrower dimensional limits has played an important part in expanding the field of application of glass. Table I gives a general picture of the dimensional variation of commercial glassware.

One of the significant developments in the accurate machine pressing of glassware is found in the manufacture of parabolic reflector shells for the all-glass General Electric Mazda Sealed Beam lamps for automobile headlighting. Since filaments must be in exact focus with respect to every part of the reflector, precise contour of the paraboloid surface is extremely important.



Courtesy American Meter Company

Fig. 3—Index window for gas meter with edges coated with metal and then soldered into a recessed metal plate

This surface, which requires no subsequent finishing, is so accurately molded that its measurement necessitates the use of reflected light.

For parts where required precision cannot be incorporated by glass molding or plastic shaping processes, it is often feasible to employ conventional grinding equipment to produce desired accuracy. A glass centrifugal pump, developed jointly by Nash Engineering Company and Corning Glass Works, which is specially designed for corrosive service and to pump 6,000 gallons per hr. against 65 ft. of head, has the impeller, volute, head plate, and mechanical seal rings all finished by grinding to close dimensional tolerances.

A more familiar application of precision grinding is standard taper stopcocks, widely employed in chemical laboratories, in which the barrels and plugs are ground to a standard taper of 1 in 10. Tubing is also available in numerous sizes having standard taper male and female ground joints for facilitating assembly of chemical apparatus.

Despite the hardness and toughness of glass in general, and borosilicate glass particularly, items which require grinding to provide the required accuracy can often be made economically. Whereas metals can be roughed out with cutting tools to approximate dimensions prior to final finishing operations, glass cannot be so treated. The availability of low-cost accurately molded blanks and machine drawn tubing, however, often reduces the amount of grinding substantially with consequent reduction in finishing costs.

Glass tubing, having extremely accurate bore or accurate taper, is commercially available. This is made by heating tubing on a metal mandrel with subsequent application of vacuum, thus shaping the bore of the tube to conform exactly with the mandrel. The difference in expansion of glass and metal permits withdrawal of the mandrel on cooling. With this method, tubing having a bore accurate within two ten thousandths of an inch is feasible. One of the commercial applications of such accurate bore tubing is in fluid meters of the "Rotometer" type.

Direct joining of metal to glass by fusing is most commonly known to the general public in the form of lamp bulbs in which lead-in wires are sealed into glass; also, in the form of glass lined vessels or vitreous-enamel ware. In addition to these, however, there are other methods of making strong simple bonds between glass and metal.

The oblong glass plate, shown in Fig. 3, has a thin firmly adherent coating of metal applied to the edges so that it can be soldered into a suitably shaped recess in a metal plate or box. The assembled frame with glass is used as an index window in domestic gas meters.

The glass centrifugal pump, previously mentioned, illustrates another type of glass to metal joint having great strength. With the impeller a hollow stub shaft is integrally molded and into this a grooved metal plug or quill is placed with sufficient clearance to receive a molten alloy bonding material. Upon cooling of the alloy the quill is permanently locked into place so that the impeller can be keyed onto the drive shaft in the conventional manner. The strength of this type of joint is entirely adequate for the torque loads encountered in service of the pump even at the high temperatures encountered in processing of fluids.

Engineers who are constantly searching for materials that are capable of meeting new and different combinations of service conditions, often hopefully consider glass but rather quickly abandon the idea with the thought "if only it were stronger." Unquestionably, the relatively low tensile strength of glass, compared with many metals, definitely precludes glass where great tensile strength is the major consideration. However, it should be borne in mind that where the unique properties of glass warrant its use, it is often possible to attain ample strength with glass by means of suitable design details.

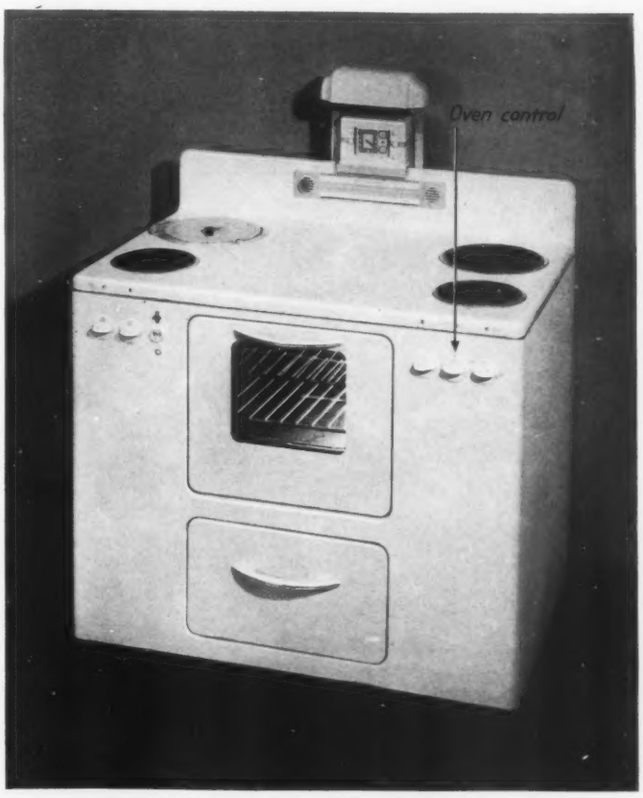
Table I—Dimensional Variation of Commercial Borosilicate Glassware

	O.D. Variation inches	Out of Round per cent of O.D.	Wall Thickness Variation
Hand blown ware			
Up to 6 in. O.D.	± 1/32	2.0 max.	100 per cent
Over 6 in. O.D.	± 3/64	2.0 max.	100 per cent
Machine blown ware	± 0.023	2.0 max.	1/32 to 1/8 in.
Hand pressed ware	± 1/32	2.0 max.	1/32 to 1/8 in.
Machine pressed ware	± 1/32	2.0 max.	1/32 to 1/16 in.
Hand drawn tubing	3/64 to 3/16	2.0 max.	± 25 per cent of nominal
Machine drawn tubing	± 1/32 to ± 1/8	2.0 max.	± 25 per cent of nominal

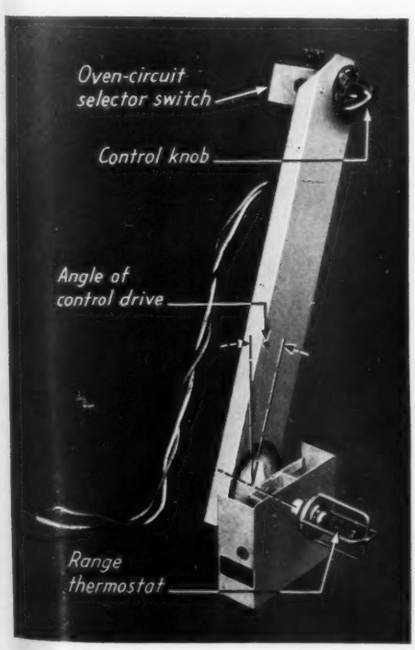
Modern Designs

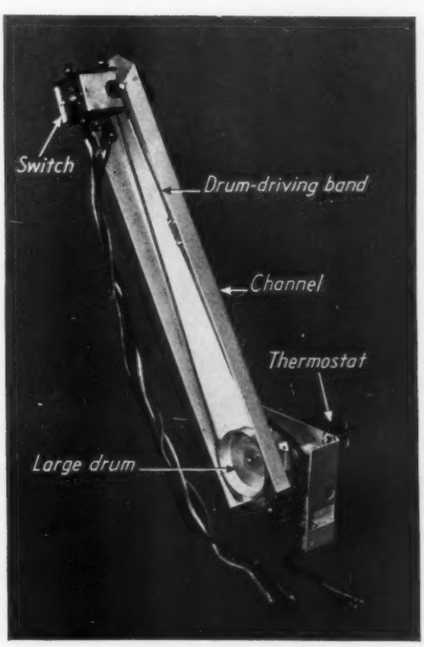
Unit Concentric Drive Simplifies Oven Control

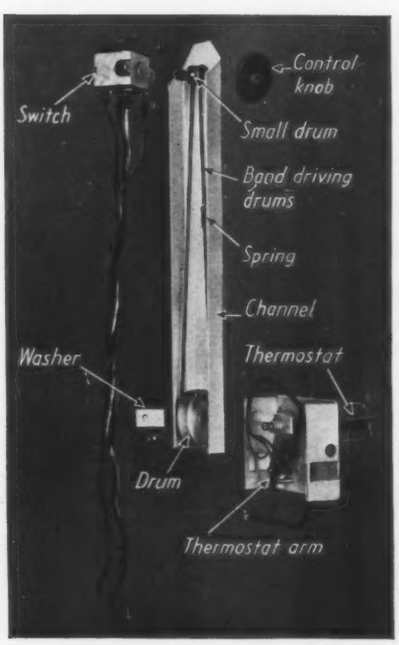
Manual operation of a domestic range oven for a baking cycle formerly required two distinct settings by the operator—first, turning the selector switch for the oven circuit to the proper setting, and second, setting the thermostat to proper operating temperature. In this Westinghouse unit control, the operations of setting the oven switch and selecting the proper baking temperature have been combined.



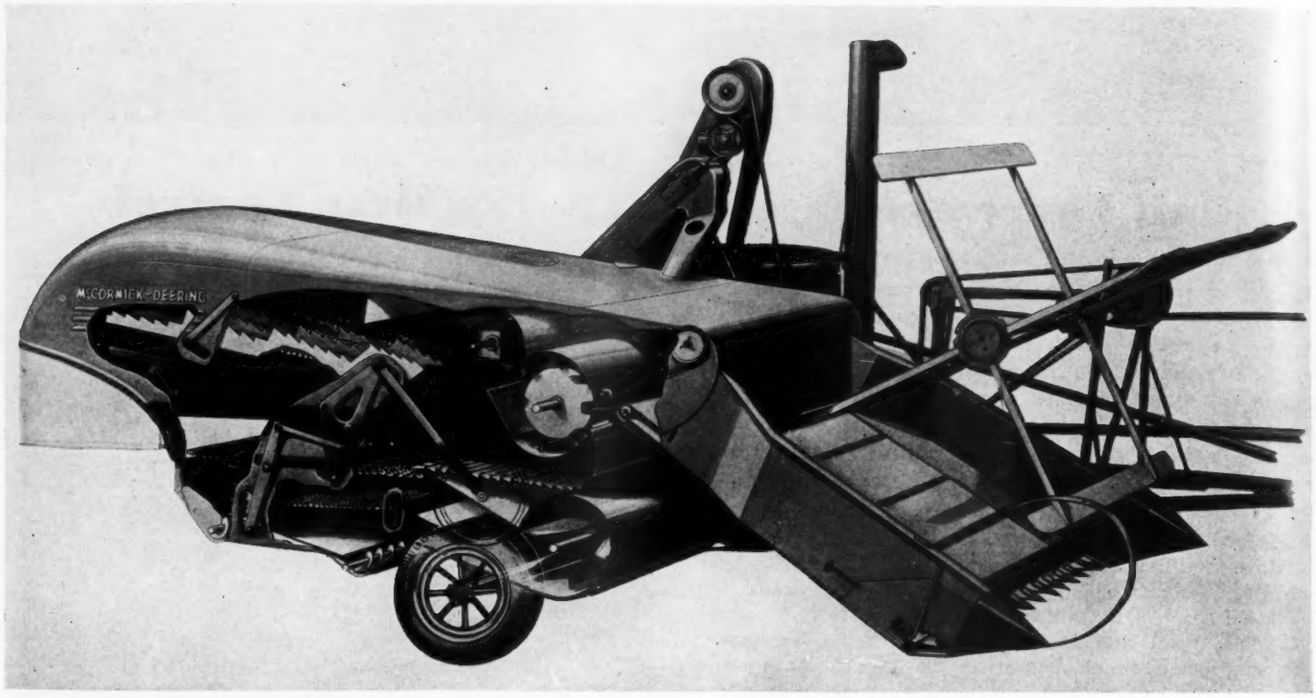
Single control knob operates range thermostat, remote control drive, and oven circuit selector switch. Thermostat and control knob shafts axes are parallel, thus extension of the length and angle of control drive permits mounting of control knob at any point on the vertical panel surface of the range. Selector switch is designed to select the baking circuit when turned from its "off" position to the lowest baking temperature on the dial and to maintain this circuit throughout the entire range of temperature as indicated on the dial. When turned to its uppermost position, it switches to the broiling circuit. Remote control drive drums are in fixed diameter ratios to predetermine angular relationship between temperature marking on setting knob and actual positions assumed by the thermostat arm. Through the use of a special keyed washer which assembles the thermostat control arm to the large drum in a fixed predetermined relationship, and the use of a single band drive keyed to the drums, and use of a milled flat on the adjusting stem for keying the setting knob, an exact relationship is maintained between adjusting knob and corresponding positions of thermostat arm. A special tongue washer fitted into a milled notch, provides non-reversible assembly.



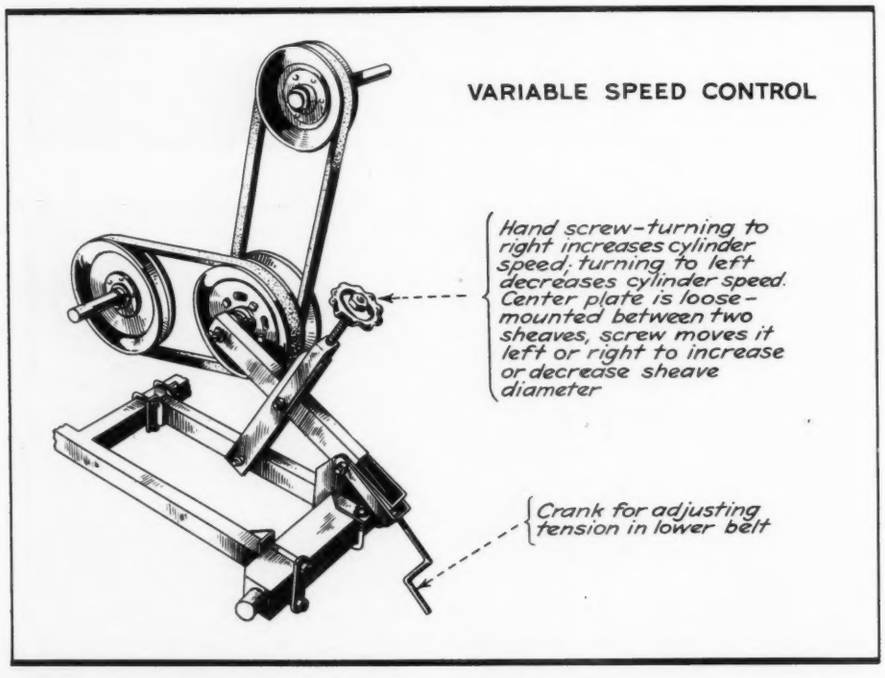




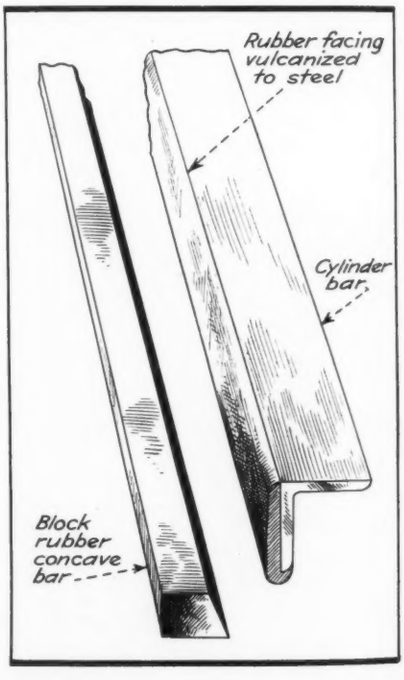
MODERN DESIGNS—Low-Price Combine for Small Farms



Four-ft. combined harvester-thresher, Model 42, of the International Harvester Company, has been developed especially for use on ten to fifteen acre farms. First cost approximates that of a power binder. Machine can be powered by small tractors of the one-plow class. The thresher has a formed sheet-steel body which serves as a frame. Controls are located on the stubble side of the machine, making it unnecessary to trample grain when making field adjustments. Control crank is easily reached from the tractor seat, permitting quick adjustment for cutting height.


VARIABLE SPEED CONTROL
Hand screw—turning to right increases cylinder speed; turning to left decreases cylinder speed. Center plate is loose-mounted between two sheaves, screw moves it left or right to increase or decrease sheave diameter
Crank for adjusting tension in lower belt

Efficiency of threshing action depends largely upon cylinder speed, particularly with the flail-type cylinder. Variable-speed device gives speeds ranging from 930 r.p.m. to 1,700 r.p.m. with belt sheaves arranged in regular position. For special crops, by reversing or changing sheaves on cylinder shaft and countershaft, speeds from 930 r.p.m. down to 400 r.p.m. can be obtained.

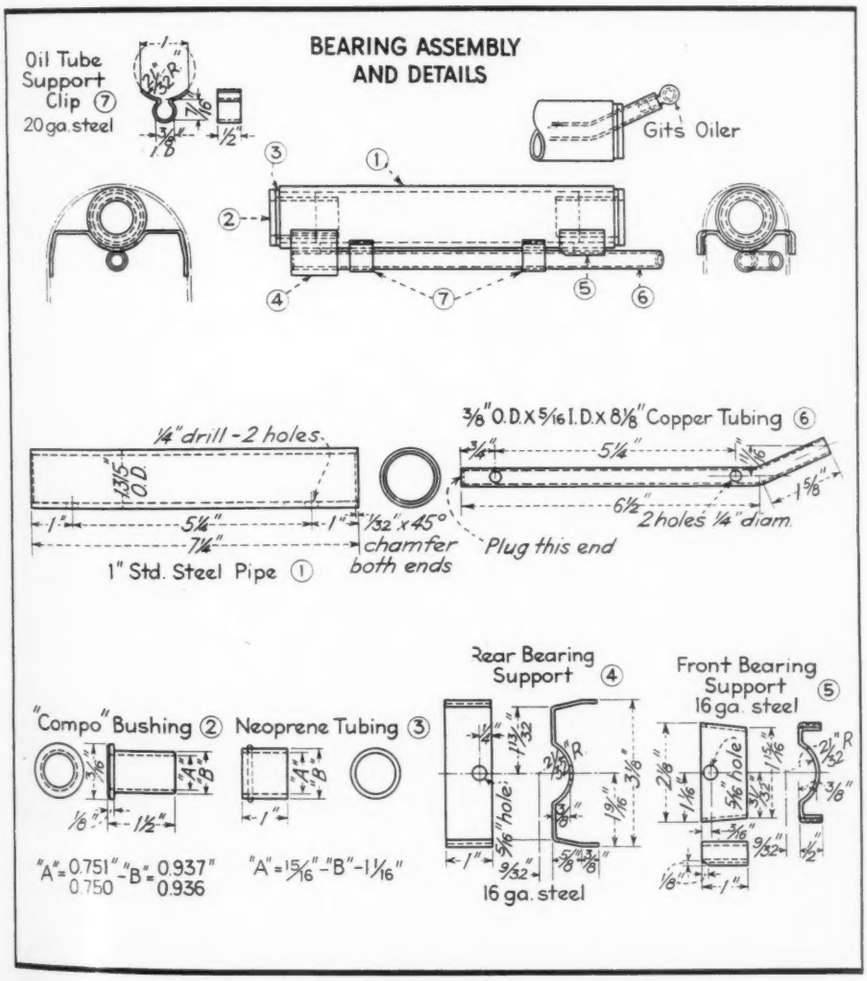


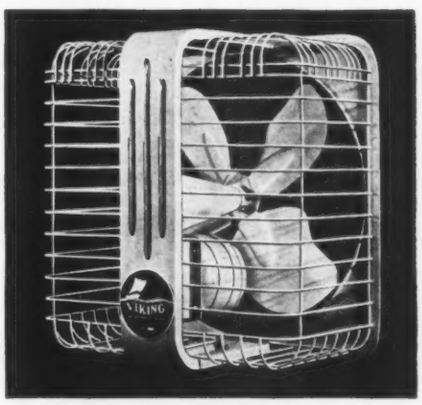
Flail-type cylinder is formed of eight spiral-mounted, angle-steel bars having rubber facings vulcanized directly to the steel. The cylinder is mounted on ball bearings and is driven by V-belts.

Block-rubber concave bars are held in place by steel clamp sections bolted to curved perforated steel plate. Curved finger plate behind plate delivers straw to straw rack.

Steel coupler holds the ends of the rubberized, weatherproof feeder canvas together, forming a smooth, grain-tight joint. A quick-tension device permits loosening at the end of day's run.

Porous Bronze Bearings Mounted in Neoprene Sleeves

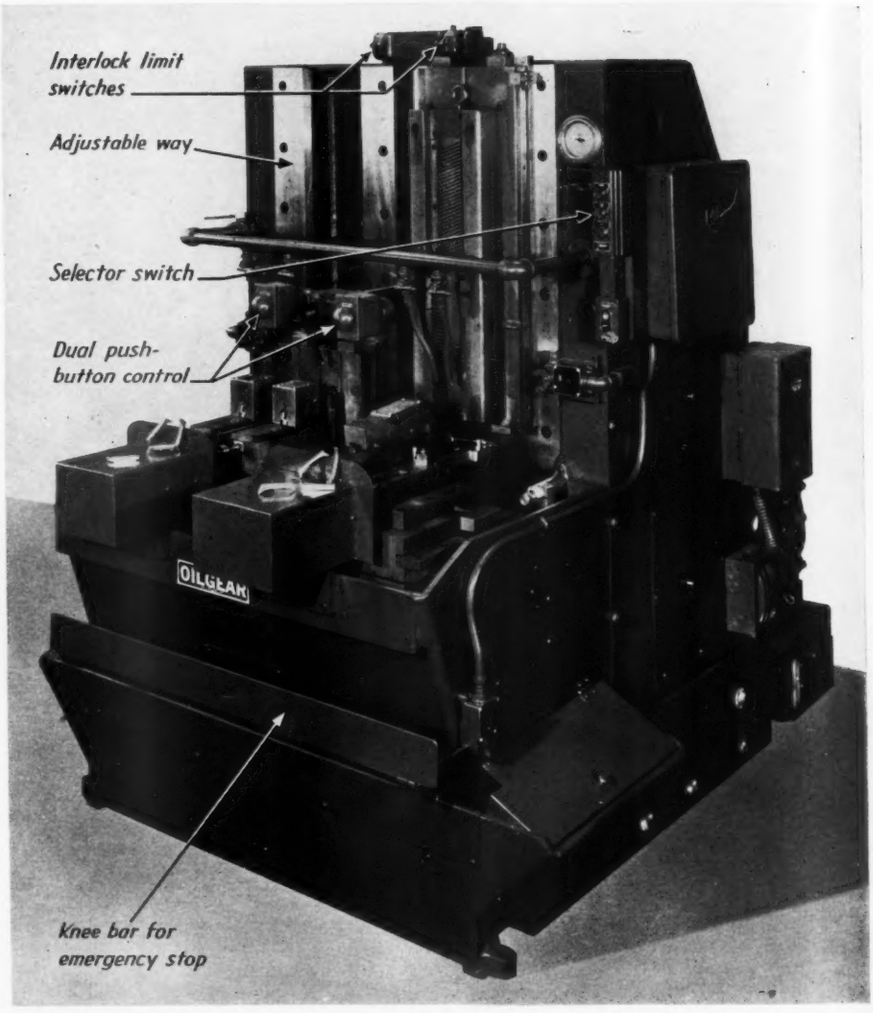

BEARING ASSEMBLY AND DETAILS
Oil Tube Support Clip ⑦ 20 ga. steel
Gits Oiler
¼" drill - 2 holes
.315" O.D.
5¼"
7¼"
1" Std. Steel Pipe ①
1/32" x 45° chamfer both ends
Plug this end
⅜" O.D. x 5/16 I.D. x 8⅛" Copper Tubing ⑥
6½"
2 holes ¼" diam.
"Compo" Bushing ②
Neoprene Tubing ③
"A" = 0.751" / 0.750 - "B" = 0.937" / 0.936
"A" = 15/16" - "B" - 1 1/16"
Rear Bearing Support ④
Front Bearing Support ⑤ 16 ga. steel
16 ga. steel



Portable window fan designed by Arthur Bennekamper, chief engineer, Viking Air Conditioning Corporation, has fanshaft supported in Compo porous bronze bearings fitted with synthetic rubber sleeves that permit self-alignment and serve as seals. Bearings are lubricated through felt wicks. Referring to the drawing, the 1-in. pipe has two ¼-in. holes drilled for the wicks. To the bottom of this pipe is assembled a bearing support bracket and an oil reservoir tube held in place by two clips. The shouldered porous bronze bearings are forced into the tube at each end. The synthetic rubber sleeves cover only ⅔ of the bearing length. Cabinet is built of No. 6 and 8 steel wire reinforced with an 18 gage steel center rib. Three-bladed fan, furnishing 3,500 cu. ft. of air per min., is driven by a ⅙ hp. motor.

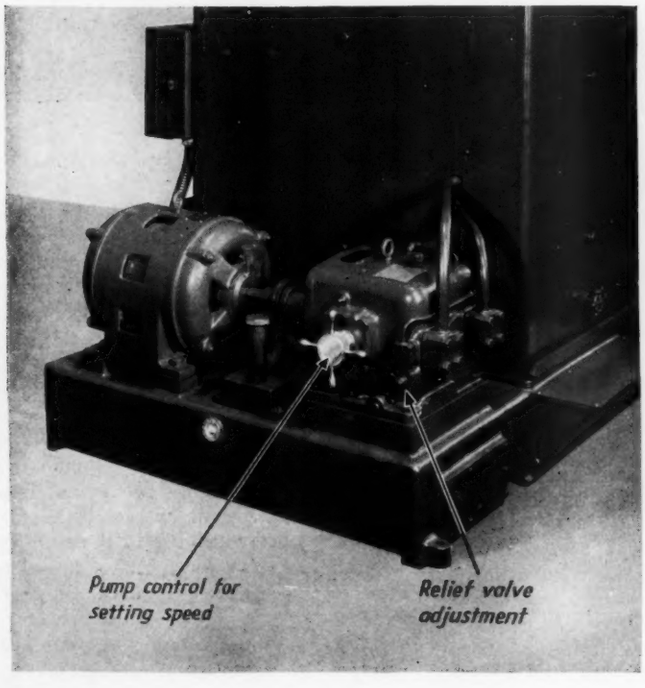
MODERN DESIGNS—Broach With Shuttling Tables

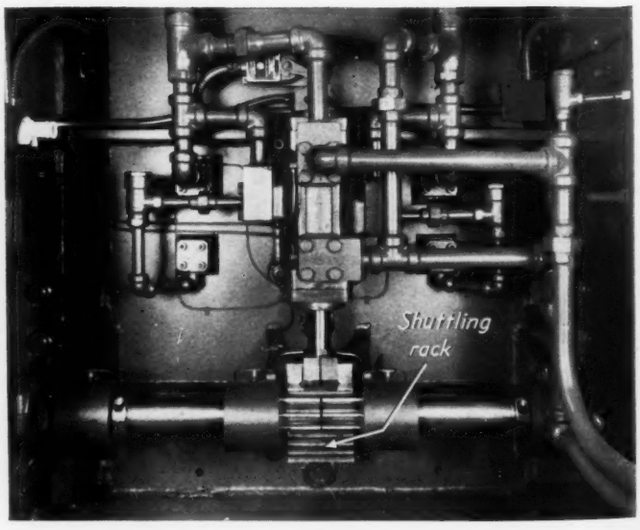
Designed for surface broaching of external slots, forms and contours, this Oilgear double-slide, pull-down broach has alternating tool slides and automatic shuttling tables which permit operator to load and unload work as one slide broaches and the other returns. All motions of tool slides and shuttling tables are interlocked.



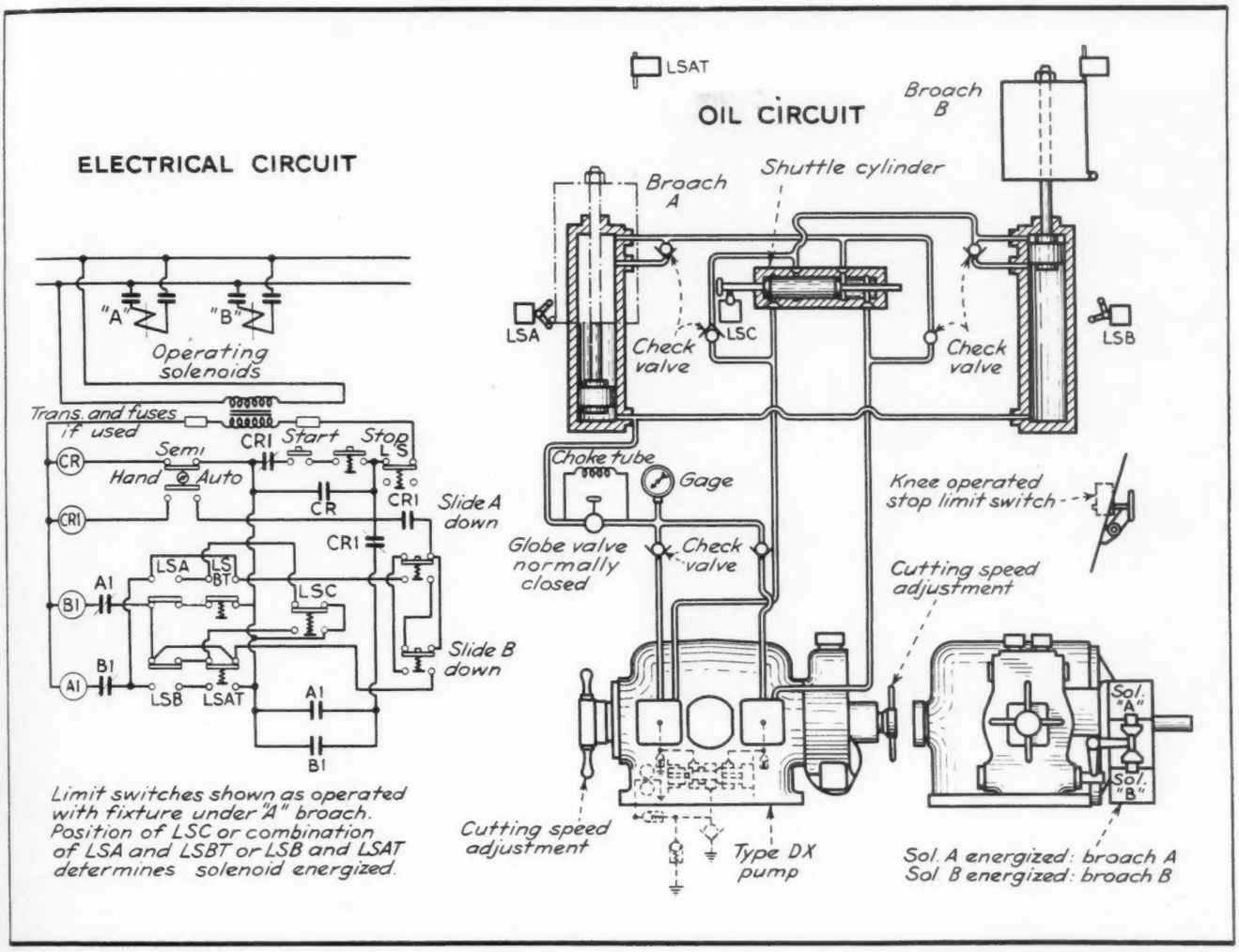
Constructional features include an all-steel welded frame and base, alloy iron tool slides and shuttle tables, hardened and ground rectangular steel ways, bored and honed steel cylinders with alloy iron pistons and rings, bronze ram guides and molded ram packings.

Oilgear type DX two-way variable displacement pump, direct-connected to motor, is mounted on an oil reservoir integral with the welded steel base. Broaching speed of each slide can be varied independently, and this, combined with alternating tool slide operation, synchronizes motions of machine and operator, saving time and effort and thus increasing production. Two adjustable relief valves, built into the pump, protect machine against overload. Maximum broaching force of each slide can be pre-set to suit tools and work. Friction, wear and power losses are reduced to a minimum through use of anti-friction bearing mountings of shaft and rotor units and automatic pressure and flood lubrication of all moving parts.

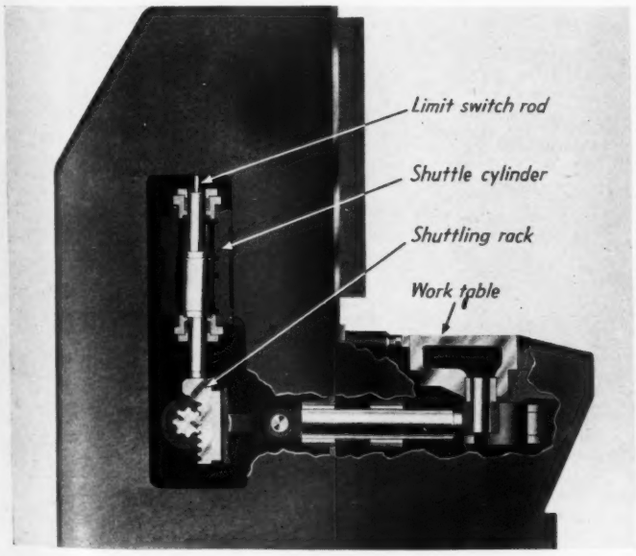


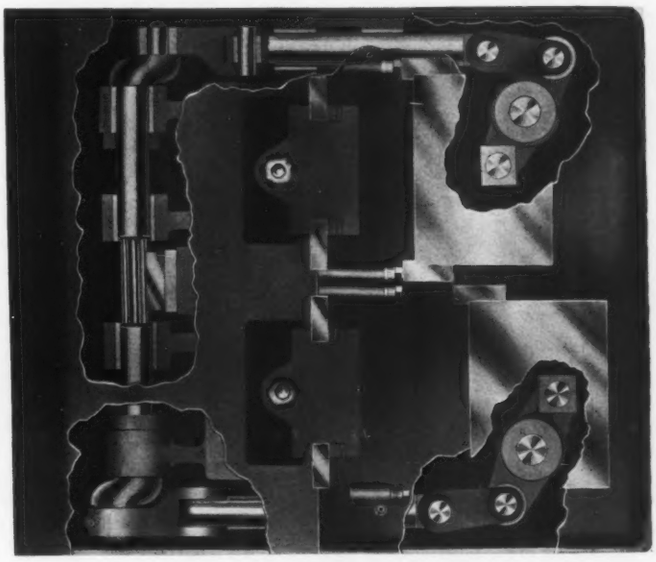


Double-acting shuttle cylinder actuates wide rack which through pinions and cranks operates shuttle tables. Cylinder ports interlock movements of tables and slides; piston must move full stroke downward before interlock port permits pressure oil to move right hand tool slide down and left hand slide up.



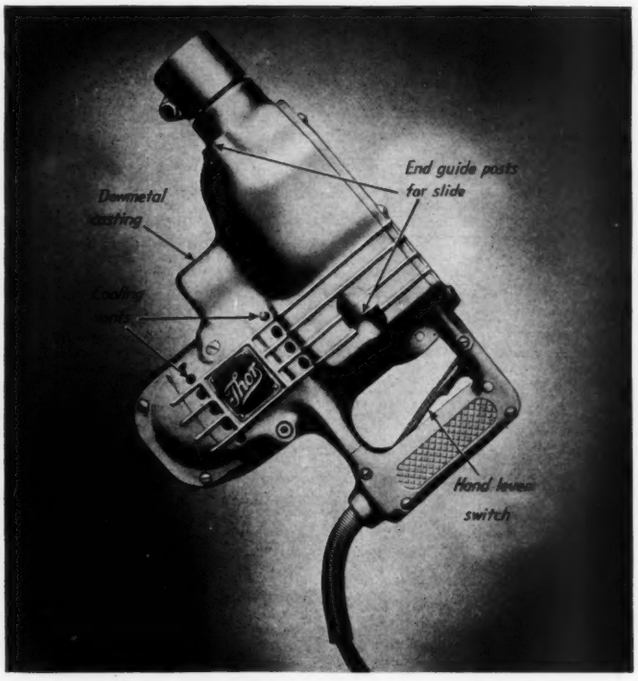
Manual, semi-cycle or full-automatic operation is available through a single selector switch. Two push-buttons are used for manual inching. For semi-cycle operation, adjustable cams on tool slides limit working stroke and automatically stop machine when cycle is completed. Full-automatic position of selector switch provides continuous operation. Knee-bar safety switch will stop machine instantly. Seamless steel tubing is brazed to steel flanged joints.

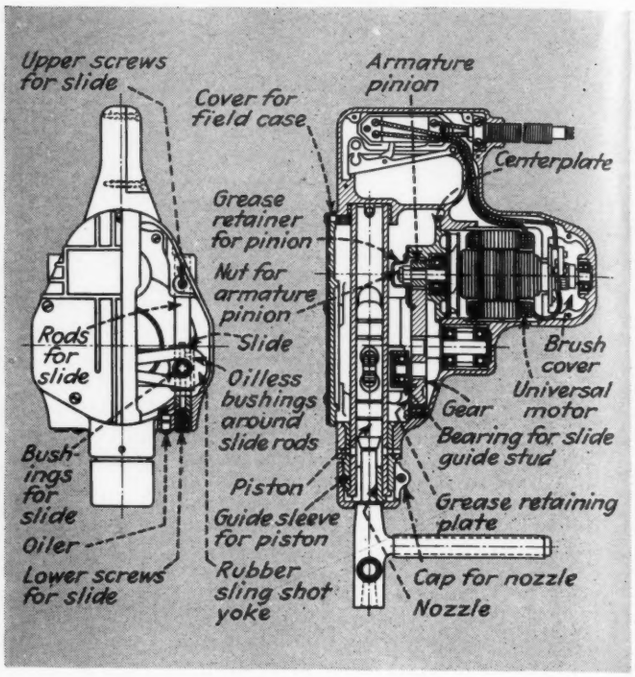




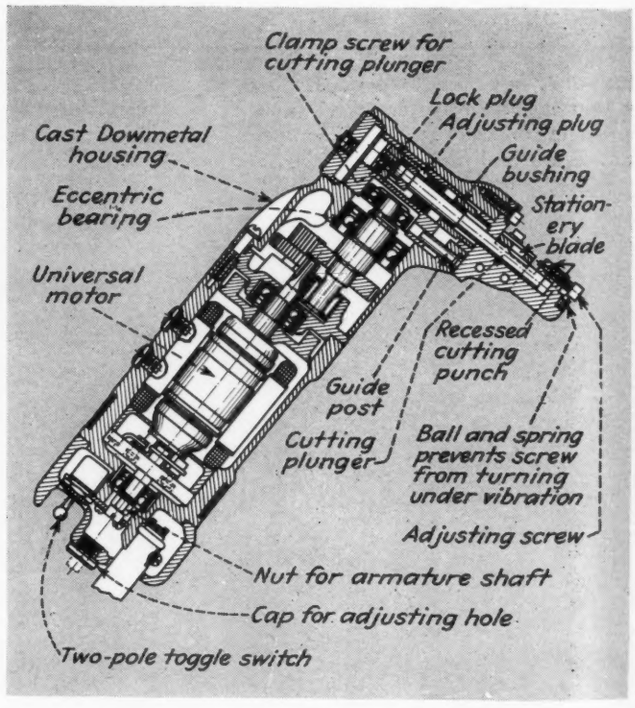
Broaching positions of shuttle tables are adjustable 5/8 in. inward and outward by eccentric crank bushings. Hardened blocks on shuttle tables contact dual, adjustable, positive stops to limit stroke for accurate repetitive operations.

MODERN DESIGNS—New Lightweight Tools



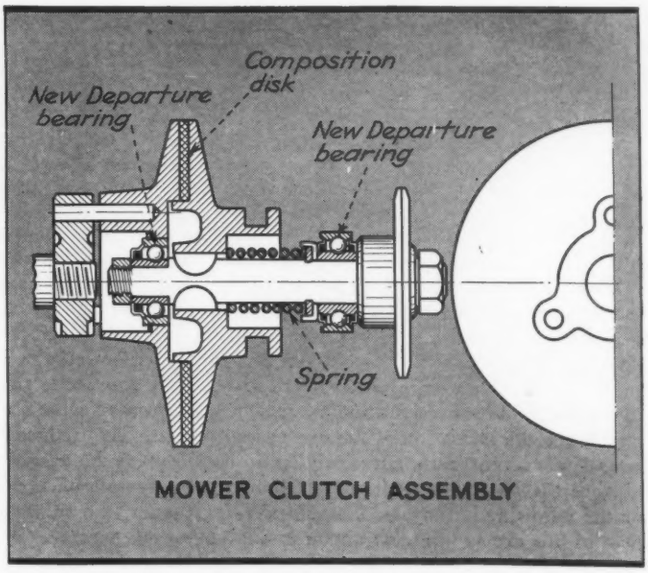


Weighing only 14 lb. the Thor-nado U 100 portable electric hammer delivers 1,600 blows per min. Light weight was achieved by compact design and use of Dowmetal housing. Rubber "sling-shot" yoke delivers power to piston from universal motor and gear train, absorbing shock and vibration. There is no metal connection between driving gears and piston. All rotating parts are fitted with large ball bearings. Hollow slide rods have oil wicks in center for automatic oiling of slide guide. Flexible connections to commutator prevent crystallization and breaking of lead wires.

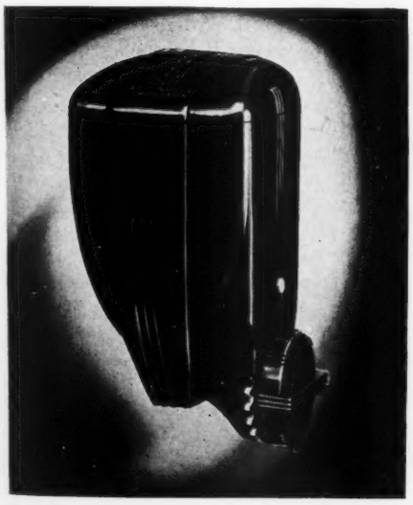


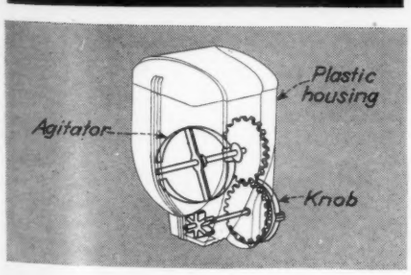
Designed for cutting sheet metal and tubing up to 18 ga. in steel and 15 ga. in aluminum, this Thor U1N portable nibbler weighs only 3¾ lb. and is powered by a universal motor. Armature pinion and reduction gears are helical cut. Reciprocating movement of the punch is obtained with a ball-bearing eccentric on a shaft supported by a large ball bearing at one end and a roller bearing at the other. Reduction gear is mounted on Oilite bearings. Cap, field case and gear case are cast Dowmetal. Removable cutting punch and cutting edge are cobalt high-speed steel.

Power Mower, New Dispenser, Miniature Engine

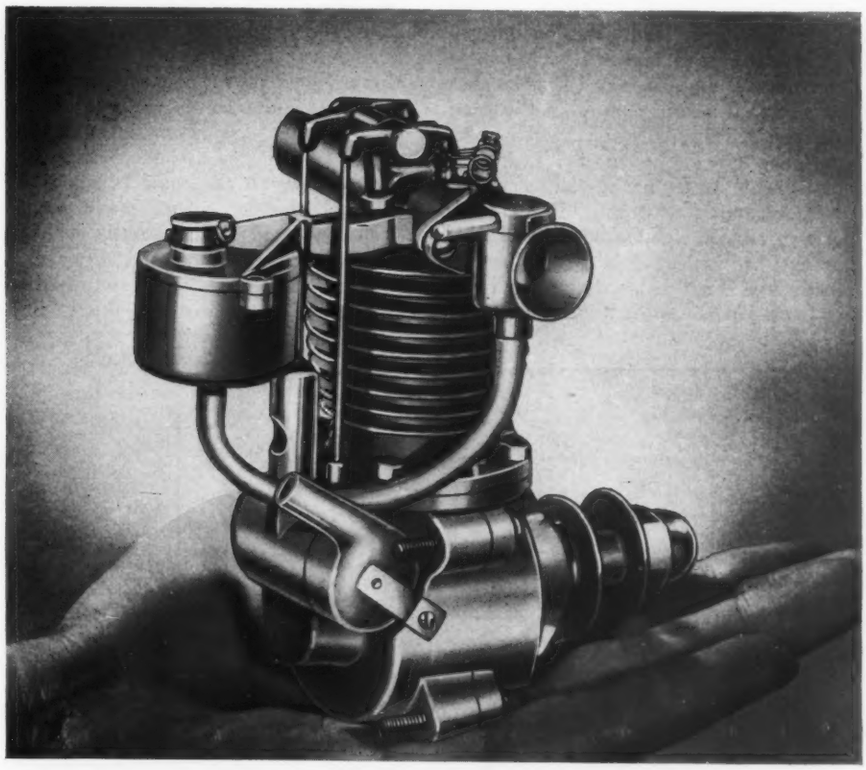


Clutch plates in the Cooper "Twenty-Five" power mower are zinc die cast. Mower is driven by ¾ hp. LeRoi engine. Garlock Klozures protect transmission shaft bearings, which are of the Chrysler "self-oiling" type. LaSalle Stressproof steel is used for transmission, wheel, and rear roller shafts. Bed knife and reel blade steel, containing 0.70 to 0.85 carbon, 0.60 to 0.90 manganese, is normalized to hardness of 37–39 Rockwell.





Built-in agitator to prevent caking features this soap dispenser styled by Vavrick and molded of Bakelite BM-427 by Modern Plastics Corporation.



Weighs 15 oz. This Feeney four-cycle overhead valve engine is claimed to be the first standard production motor of four-cycle design ever offered to model builders. Engine has drop-forged valves, a double bearing crankshaft, splash lubrication and oil traps over high pressure bearing areas. Furnishes ⅔ hp.

NEW CONDENSER CIRCUITS

For Suppressing D. C. Arcs

DR. C. G. SUITS and J. A. VAN LUND
General Electric Research Laboratories

WHEN a switch or relay in an a.c. circuit is opened, the current reversals are of prime importance in suppressing or extinguishing the arc formed. Although the duration of the "current zero" when the current reverses in direction twice each cycle is infinitesimally short, the reduction in temperature and hence the ionization of the arc gases near the current zero effectively extinguishes the arc by preventing restriking on the following half cycle. The effectiveness of this arc suppression action in a.c. circuits is illustrated convincingly by a comparison of the ratings of the same switches and relays for a.c. and for d.c. circuits.

D.C. Versus A.C. Rating

As an example, consider a small size double-pole, double-throw relay with an a.c. rating of 10 amp. at 125 volts. However, the 125-volt d.c. rating of this same relay is only 0.5 amp. for a single contact on resistance load. Putting the two contacts in series makes it possible to interrupt 1.0 amp. d.c. at 125 volts, but a conservative rating would not exceed 0.7 amp. Thus, a given switch in a resistance circuit has a d.c. rating of only about 1/15th or 1/20th its rating for alternating current. The comparison is more striking when it is realized that the a.c. rating of a small switch of this type is not primarily an interrupting limit, but a value determined by the size of the contacts and terminal connections. The interrupting limit of this small relay is in excess of 50 amp. at 125 volts a.c.

In order to increase the capacity of a switch or relay in a d.c. circuit it is common practice to shunt a condenser across the contacts, the connections being permanent. This reduces the arcing at "break" because the current in the arc is reduced by reason of the charging of the condenser, the voltage across the condenser rising together with the arc voltages. However, when the contacts are again closed there is an excessive current through the contacts at the moment of "make" the condenser then discharging. In practice, this difficulty is usually overcome by putting a resistance in series with the condenser, which however somewhat reduces its effectiveness for arc suppression.

An improvement on the permanently shunted condenser is to arrange the circuit so that the condenser is not connected across the contact until the moment when the contacts are opened. That is, the uncharged condenser is connected across the contacts simultaneously with the opening of the contact. The advantage of this over the first method is that there is no high current through the contacts when they are first closed, because the condenser is disconnected simultaneously with the closing of the contacts and hence there cannot be a surge such as would be caused by the condenser voltage if the condenser remained in the circuit after the contacts had opened.

In the two methods described above, the condenser is charged with the same polarity as the polarity of the voltage drop across the arc.

Oppositely Charged Condenser

A much more substantial improvement is obtained when the condenser is connected so that it will be charged oppositely to the potential of the voltage drop across the arc. In this arrangement the oppositely charged condenser is connected across the gap or contacts after an optimum contact separation has been reached. The condenser will then discharge by sending a current through the arc in a direction opposite to the arc current and will subsequently charge in the same polarity as the arc. In Fig. 3 is shown the curve of the voltages or voltage changes that occur when the contacts are opened.

The curve in Fig. 3 shows that following the opening of the contacts, and establishment of the arc the condenser is connected across the contacts at t_o. Because the condenser voltage opposes the arc voltage, the voltage of the latter is thereby made negative momentarily. The voltage across the gap then rises and if sufficient time has been provided to allow the arc gases to cool and deionize, which depends on the condenser capacity, the voltage across the gap will rise to line

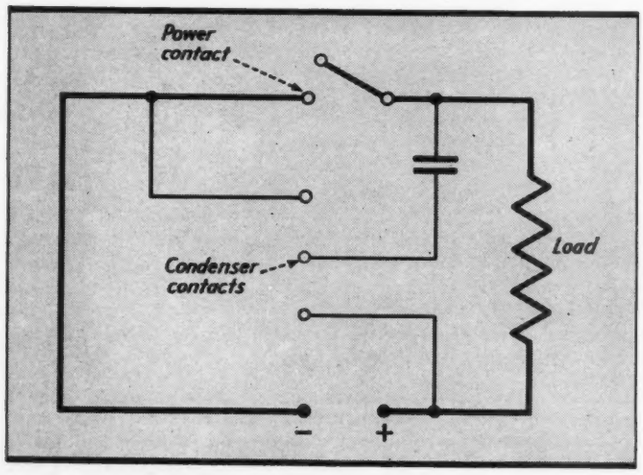


Fig. 1—"Reversed charge" condenser arc suppression method, applied to double-pole double-throw contactor

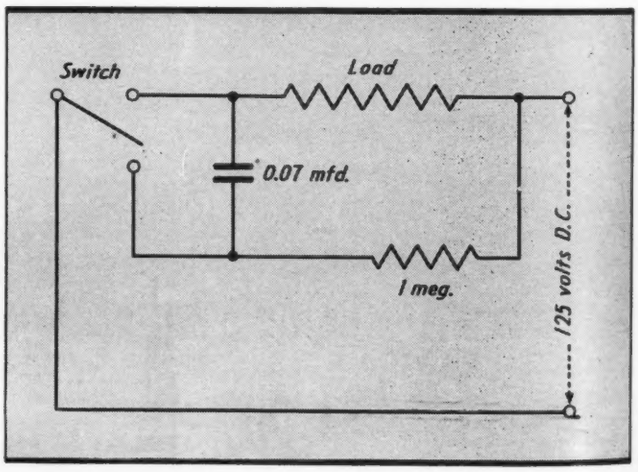


Fig. 2—Diagram showing the "reversed charge" method applied with single back contact

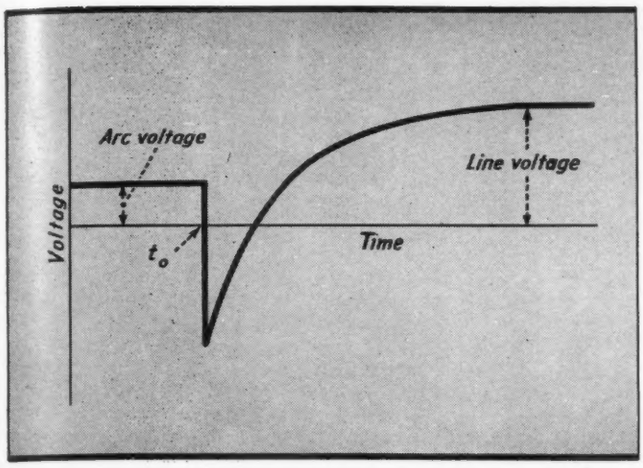


Fig. 3—Oscillograph trace showing current zeros impressed by reverse charge condenser

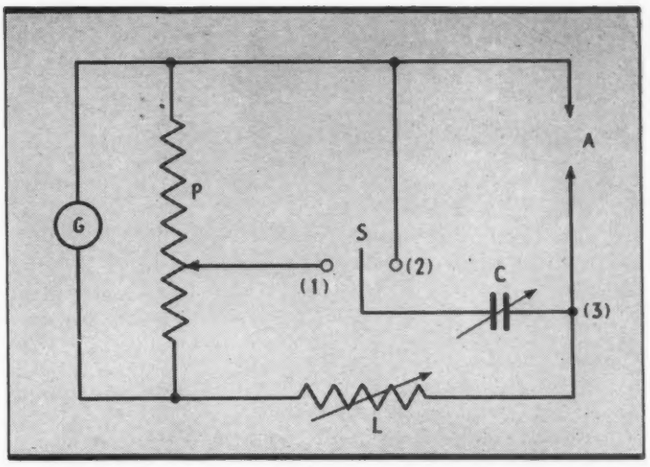


Fig. 4—Diagram of test circuit for observing reversed charge arc suppression in contact A

voltage. As can be seen from the curve, this method in effect gives the d.c. circuit a current zero.

In order to obtain data on the effect of the capacity of the condenser and the length of the gap across the open contacts, a series of tests was made using a circuit diagram as shown in Fig. 4. Copper electrodes were used for the contacts and a generator voltage of 250 volts was used in this particular test. The gap length at *A* was made adjustable by means of a threaded screw adjustment. The lower electrode could be raised until contact was made and then lowered, thereby striking the arc. By adjusting the potentiometer, any voltage less than load voltage could be applied to the condenser by making contact at (1). When the switch *S* was thrown to position numbered (2) the condenser was thrown simultaneously across the gap.

Effect of Capacitance

One series of tests was to determine the interruption ability as a function of the capacitance of the condenser. The curve obtained from these tests is shown in Fig. 5 in comparison with the two alternative condenser suppression methods described above. The condenser voltage was 125, the gap was 1 mm. long and the line voltage was 250. The test procedure was to fix the capacitance, vary the current, increasing it or decreasing it until the maximum current at which the arc was extinguished was obtained. The electrodes were closed and the switch *S* was thrown to position (2). This was repeated until the maximum current that could be interrupted 50 times successively without a sustained arc on any trial was determined. This gave one point on the curve.

The same procedure was followed on the permanently shunted condenser, using the same circuit diagram except for the omission of the auxiliary switches. After this series of tests, the terminal (1) was connected to the terminal (3) and the same test sequence was followed in order to obtain the data for the suddenly applied uncharged condenser.

The significance of these curves is apparent. To interrupt a current of 3 amp. with a permanently shunted condenser requires a 3.5 mfd. condenser, while with a suddenly applied uncharged condenser a 1 mfd. condenser would do the work. But with the new oppositely charged condenser method, one with polarity opposite to that of the potential across the arc, a capacitance of only 0.05 mfd. was required. For the range of 10 or 15 amp. and higher, a shunt condenser or suddenly applied uncharged condenser would be out of the question because of the large capacity required, whereas an oppositely charged condenser of only 0.6 to 1.2 mfd. capacity could be used successfully. The condenser economy of such an arrangement is obvious.

Importance of Gap Length

The surprising effect of gap length when the oppositely charged condenser method is used is shown by Fig. 6. This curve of interrupted current vs. gap length shows the upper limits of interruptibility for a given value of capacitance, and was obtained in the same manner as the previous curve. The curve in Fig. 6 shows that the interrupting ability when using a 1 mfd. oppositely charged condenser is a maximum when the gap length is 3.5 mm. and a minimum somewhere between 10 and 20 mm. This decrease in interrupting ability with increase in gap is directly counter to the usual trend in d.c. interruption, but must

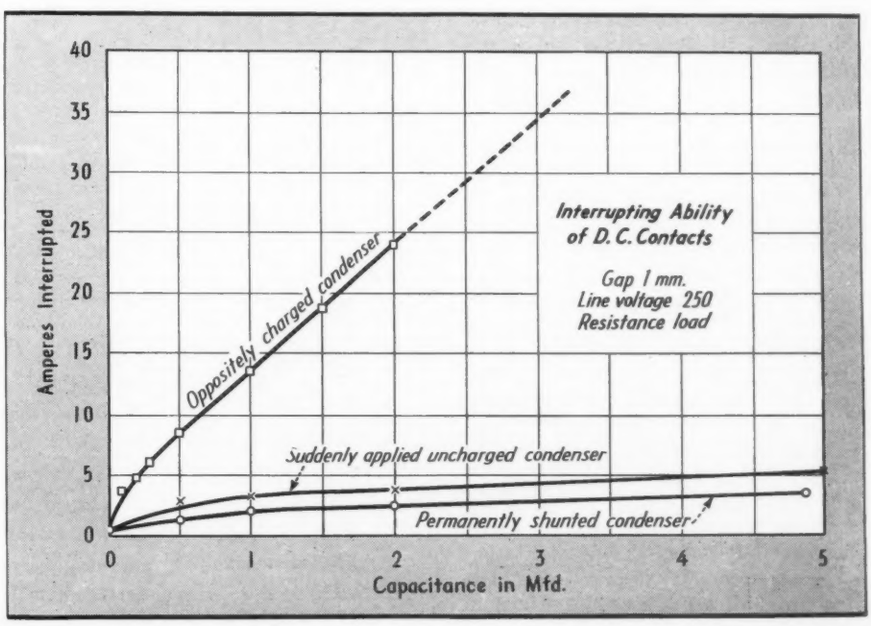


Fig. 5—Comparison between three methods of applying condensers for arc suppression

be taken in account to obtain the full advantage of the new method. For design purposes, a series of curves for various condensers would be required and these measurements are taken preferably on the actual switch to be used. For example, if one wished to design a contactor to use with a maximum capacitance of one mfd. in the new circuit the largest current that could be interrupted with certainty would be 16 amp. at a gap of 3.5 mm. If the gap should be increased to 10 mm. the maximum interrupting limit would be reduced to only 2.5 amp. which illustrates the necessity of taking account of the gap length in the design. This gap length phenomenon agrees very well with modern cooling theories of arc interruption, and shows that as the arc length is increased from 3.5 to 11 mm. the decrease in effectiveness of heat flow to the electrodes is far more harmful than the gain in flashover strength that accompanies the wider gap. For that reason it is desirable that for effective cooling of the arc gas the contact diameter should be as a minimum greater than the gap length.

Increased Ratings Obtained

Summarizing the results of these investigations the "oppositely charged" condenser is highly effective in extinguishnig a steady arc in air at atmospheric pressure. Used in this connection a given condenser will extinguish a steady arc current ten times as high as can be extinguished with the usual condenser connection which employs a suppression condenser permanently connected directly across the contact, and six times higher than the arc current that can be interrupted by suddenly applying an uncharged condenser across the arc. The oppositely charged condenser is usually charged by connecting it across the load, but it has been found that the voltage to which the condenser is charged is not critical as long as it remains oppositely charged to a voltage as great as that of the arc.

The special effectiveness of the oppositely charged condenser in arc extinction has immediate practical application to small switches and contactors as shown by the following three examples:

(1) As mentioned above, the small double-pole, double-throw relay has an a.c. rating of 10 amp. at 125 volts. The 125-volts d.c. rating is 0.5 amp. for a single contact on resistance load. Putting the two contacts in series will interrupt 1 amp. d.c. at 125 volts, but the relay would have to be rated at approximately 0.7 amp. By the use of the contact of this relay for the power circuit and the other contacts for switching the oppositely-charged condenser, the d.c. rating can be made equal to the a.c. rating. The circuit for this arrangement is shown in Fig. 1. This circuit will actually interrupt 16 amp. at 125 volts d.c. and can safely

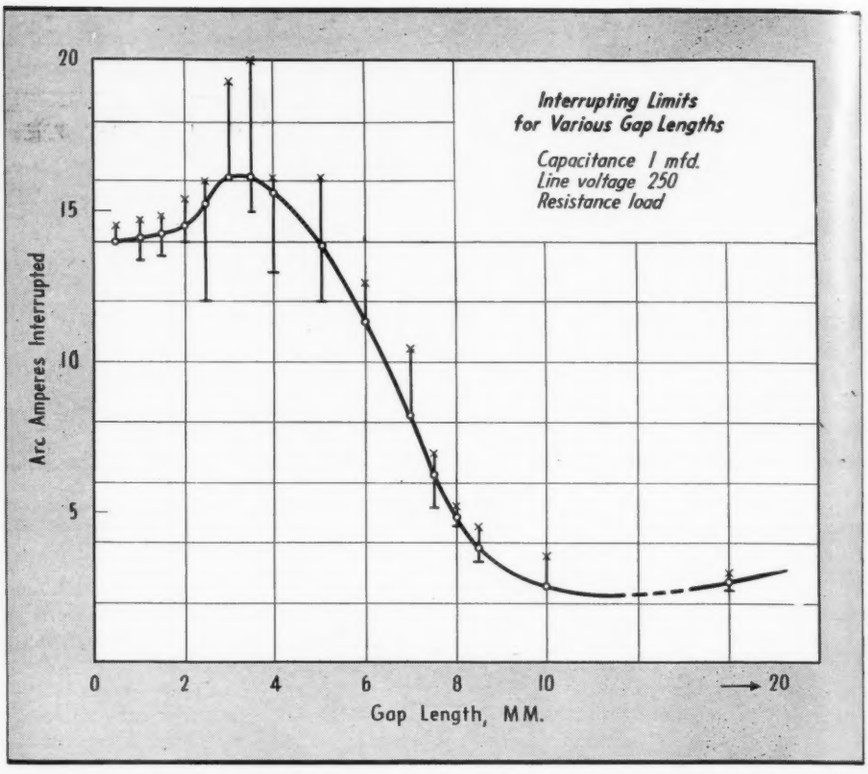


Fig. 6—Curve showing the importance of proper contact separation for reverse charge arc suppression

be rated at 10 amp. d.c., and the capacitance required is only 1/20 mfd. This relay can by this means be given a d.c. rating equal to an a.c. rating, whereas at present it has practically no useful d.c. rating.

(2) With the same circuit and 1/20 mfd. oppositely-charged condenser, another device tested interrupted 24 amp. at 250 volts d.c. But two gaps in series, without the condenser, interrupted only 1.9 amp. d.c. at the same voltage.

(3) With the use of a single-pole, double-throw snap switch rated at 10 amp., 125 volts a.c., it was found that on 125 volts d.c. this switch would interrupt a maximum of 1 amp. At higher current a steady state arc was established. With the circuit shown in Fig. 2, a 10 amp. d.c. was interrupted with a 0.07 mfd. condenser and a 1 meg. resistance.

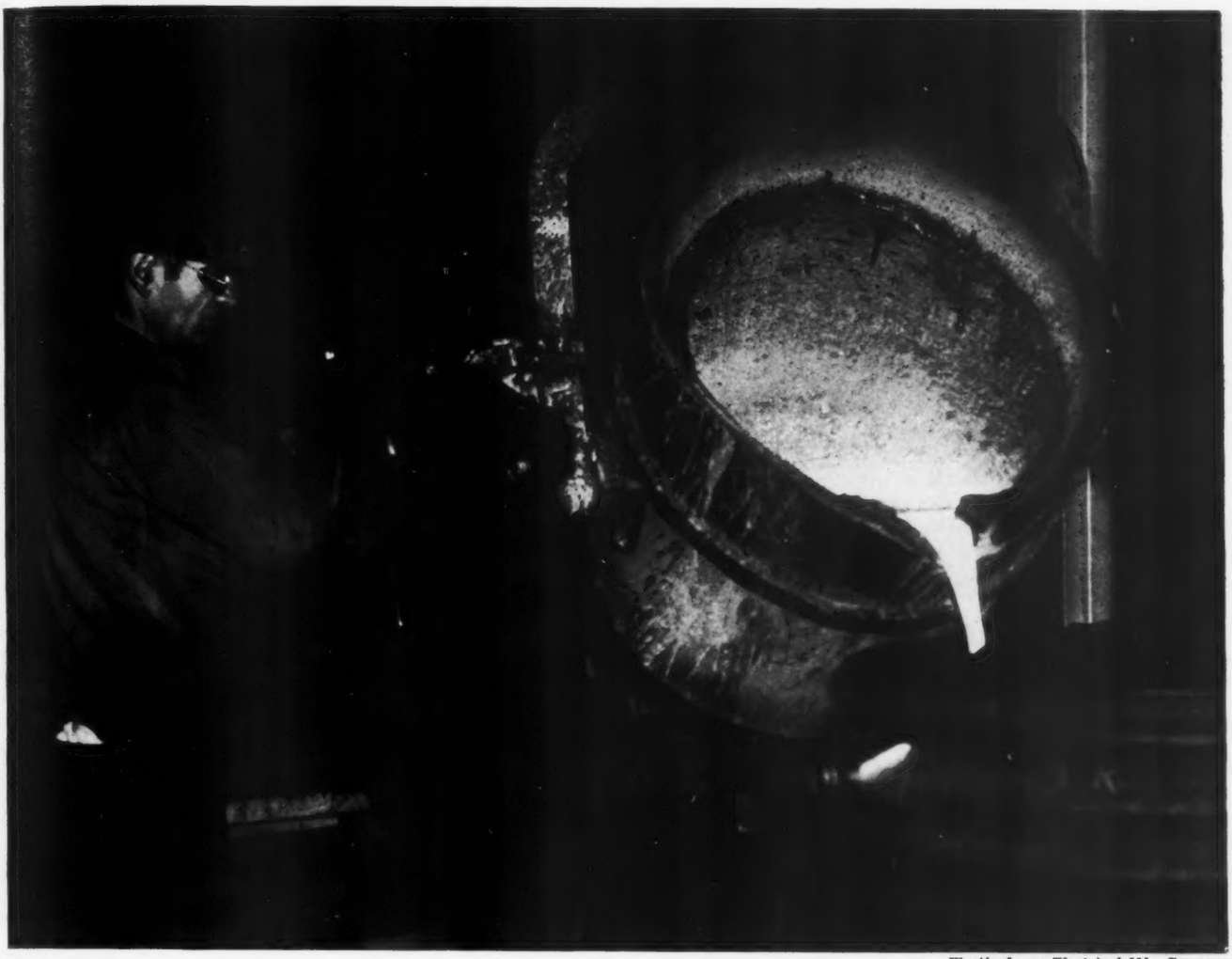
In practical applications of this method, the most important of which has been as overload switches on d.c. motors, where the interrupting duty is high but the service infrequent, it has been found possible to simplify the condenser switching method and simultaneously increase the reliability of the method by the use of the circuit of Fig. 2.

Here the suppression condenser is permanently connected across the load through a high resistance and a single back contact performs all the switching functions. This makes it certain that the capacitance is charged when required, independent of the proper functioning by auxiliary contacts.

These three randomly selected examples of the effectiveness of the oppositely-charged condenser clearly indicate its possibilities when applied to small switches in d.c. circuits.

Current Quotations

"The future, indeed, looks bright. We know so little about nature's basic underlying principles today that it is incredible that anyone should think that our knowledge of natural laws is anything but exceedingly small when compared with the vast amount that is listed in the unknown column. This alone should be encouraging, for if we can accomplish all that we have with such a poor understanding, it is reasonable to expect vastly better results as we obtain more basic knowledge."—GEORGE H. BUCHER, *President of the Westinghouse Electric & Manufacturing Company.*



Westinghouse Electric & Mfg. Company

CAST IRONS

The Control and Improvement of Their Properties

C. H. LORIG
Supervising Metallurgist, Battelle Memorial Institute

MUCH of the development in the past that has raised the casting industry to its present level has been the product of diverse researches both of fundamental and practical natures. This progress has been continuous and fast, especially during the past decade, and new developments will continue to come at an ever increasing rate because an ever increasing amount of energy and thought is being given to the matter. The developments in cast iron are typical of the progress that has been made in both iron and steel castings.

While alloying of gray iron dates back 25 years, the use of alloys started a train of events that have had an astonishing influence on the gray iron industry as a whole. It has made the industry high-strength conscious, with the result that there has been a sound growth in the manufacture and use of irons whose strength far exceeds what previously had been the rule for gray iron. The natural effect was to extend the field of application for cast iron, to develop irons better adapted to given requirements, to utilize more effectively those inherent characteristics possessed by cast iron such as wear resistance, damping capacity, low notch sensitivity, and to widen considerably our knowledge of engineering qualities and compositions of cast iron. Along with this there has been a general movement toward making better irons without alloying. Mainly through the control of carbon and silicon content and with a growing appreciation of the influence of structure on

the properties of irons, unalloyed irons are now being made consistently, in some foundries, with strengths well over 40,000 lb. per sq.in. That is a remarkable achievement. It is something that many foundries are now doing and every gray iron foundry will soon be able to accomplish as a routine matter.

The engineering properties of cast iron are more commonly defined in terms of static properties. Of equal or greater importance in some applications of cast iron are the need for such qualities as good wear resistance, high damping capacity and low notch sensitivity. Developments toward producing cast irons which excel in one or more of these latter qualities have been highly successful.

One of the outstanding qualities of cast iron is its good frictional characteristics. That is generally conceded. Much effort has been expended in investigating wear properties of cast irons both under service conditions and in

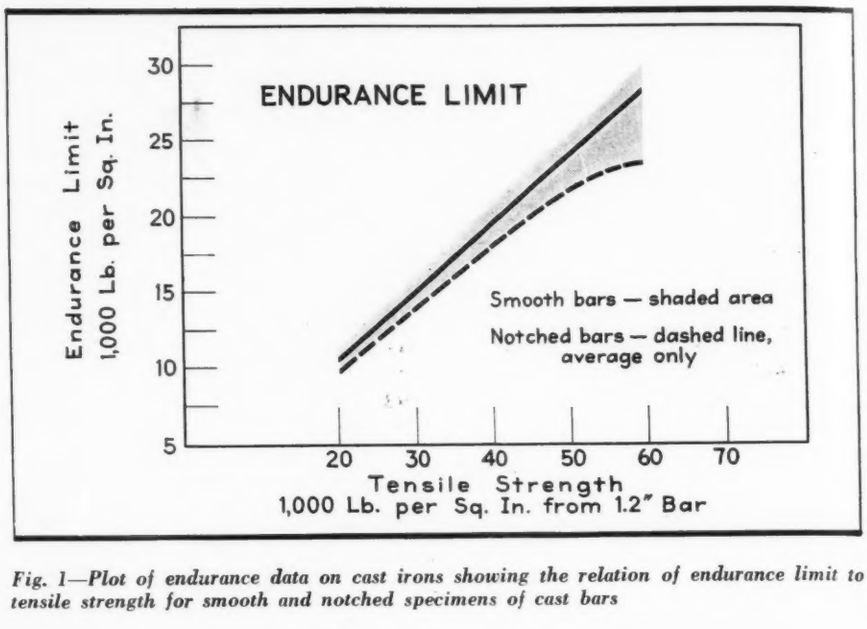


Fig. 1—Plot of endurance data on cast irons showing the relation of endurance limit to tensile strength for smooth and notched specimens of cast bars

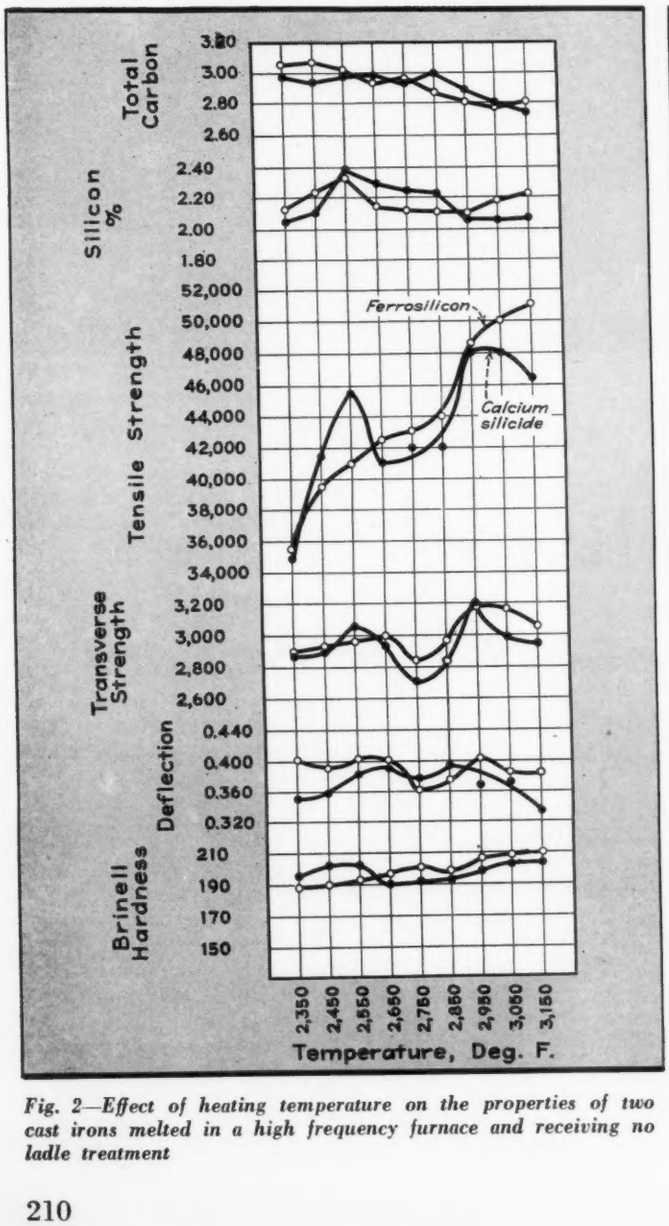


Fig. 2—Effect of heating temperature on the properties of two cast irons melted in a high frequency furnace and receiving no ladle treatment

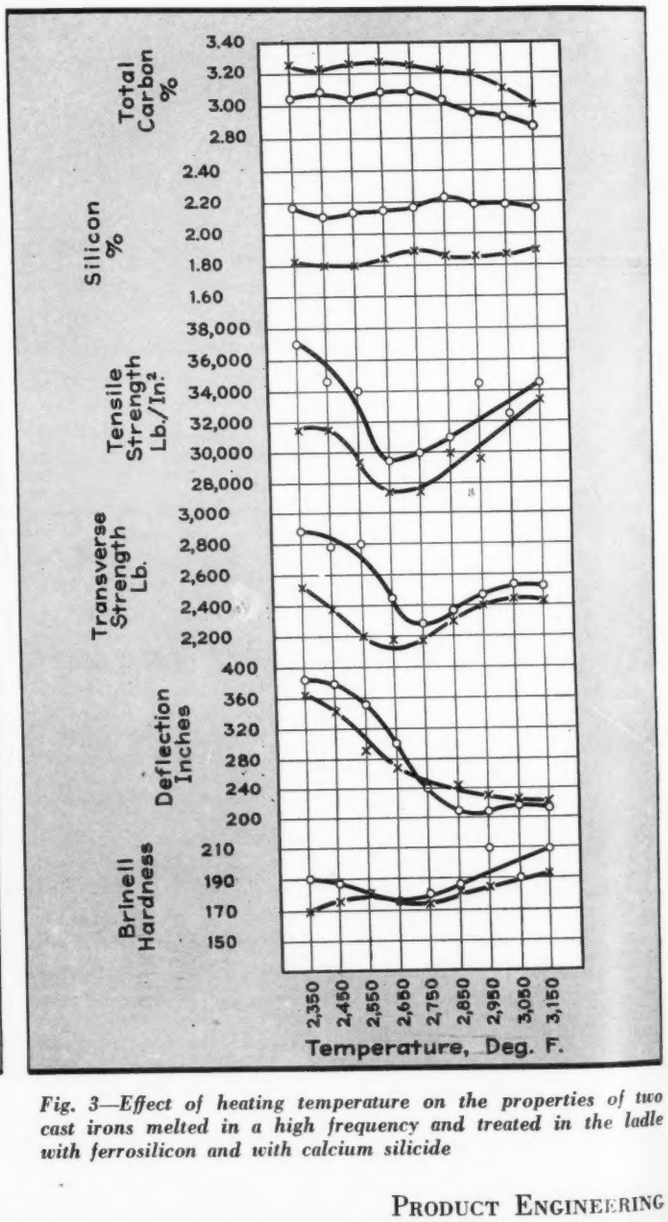


Fig. 3—Effect of heating temperature on the properties of two cast irons melted in a high frequency and treated in the ladle with ferrosilicon and with calcium silicide

tests that supposedly simulate conditions in service. While such tests frequently provide data highly desirable to the problem in question they seldom give information of fundamental importance to the general problem of wear between similar and dissimilar metal parts, because of the complexity of the wear problem.

No numerical figures for ranking cast irons as to their wearing properties can be quoted, for such figures would have little meaning. Naturally the mating material used in wear tests has the same importance as the material that is being tested. What the wear tests are designed to show is one of four things, the resistance of the iron to abrasion, or to corrosion, or to galling (seizing), or to cutting, each of which typifies a particular kind of wear resistance.

Abrasion Resisting Irons

Both research and service performance have indicated that cast irons with fully pearlitic structures consisting of alternate lamellae of almost pure iron and iron carbide the total carbon of the structure being somewhat under 0.9 per cent, and with fairly generous amounts of graphite in coarse, flake form resist abrasion and galling to a high degree. A ferritic iron, one with much free iron in its structure, always wears more rapidly than a pearlitic one. Other properties of irons such as their hardness and the presence of hard particles dispersed in their structures also appear to be of some significance from the standpoint of wear resistance, although such hard particles may cause excessive wear on the mating surface. The importance of their ability to form and maintain a film on wearing surfaces has only recently been recognized. In the future much more should be heard of the role played by these surface films.

Cast iron possesses a higher damping capacity than steel. Soft irons have a high damping capacity and as the strength, hardness, and stiffness of the irons increase, the damping capacity is lowered. But even high-strength irons have greater damping capacities than steel.

A great deal of interest in the damping capacities of cast irons has been manifested lately owing to the fairly widespread adoption of cast iron for crankshafts. The higher damping capacities and lower notch sensitivities of cast irons have been extremely important factors in causing this shift from steel crankshafts.

The damping capacity, which is defined as the per cent energy loss per cycle of free vibration, calculated for stresses equivalent to 15 and 35 per cent of the tensile strength, for several plain and alloyed cast irons are summarized in Table I.

It seems significant from an engineering point of view that at working stresses equal to 15 per cent of the tensile strength, the stronger alloyed irons are superior in damping capacity to the unalloyed irons. The conditions reverse at working stresses equal to 35 per cent of the tensile strength. However, structures are seldom designed for working stresses much above 20 per cent of the tensile strength.

Endurance Limits

Cast irons differ from most engineering materials in their low susceptibility to notch effect. This has been demonstrated many times. It has been observed, however, that as the tensile strength of iron increases, the irons begin to show an effect of the notch, the notched bar endurance limit falling slightly below that for the unnotched bar. The endurance data on cast irons cited in the literature have been summarized in the composite curve of Fig. 1 where the relation of endurance limit to tensile strength for both smooth and notched specimens is shown.

Tremendous strides have been made in the technique of manufacture of gray cast irons and they are finding a new place as an engineering material because of the improvements in properties.

Lowering of the carbon by using higher steel charges in the cupola, or by better regulation of the cupola to give lower carbon irons have been two of the most successful means for raising the strength of the irons. These practices have led to others which primarily concern a better control of graphite size and distribution. Thus there is the general tendency to raise the temperature of the metal from the cupola and, further, to make ladle additions of ferrosilicon, calcium silicide, and various other graphitizers.

Superheating of cast iron, as it is often called, came about with the advent of electric furnace melting. By raising the temperature, which was easily accomplished in the electric furnace, a refinement in graphite size in the iron was obtained. This refinement in the graphite, coupled with a more ideal distribution, improved the strength of gray iron without changing its composition. The discovery that irons could be strengthened by superheating has had a significant influence on melting operations today. But at present the results of superheating are not always as we would like to have them; sometimes they are bad.

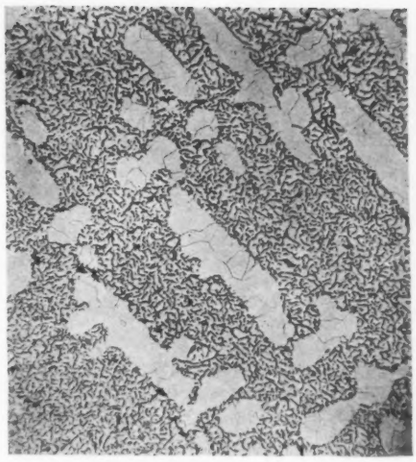


Fig. 4—Microstructure (X100) of sulphur-free cast iron showing the characteristic distribution of graphite in the absence of sulphur

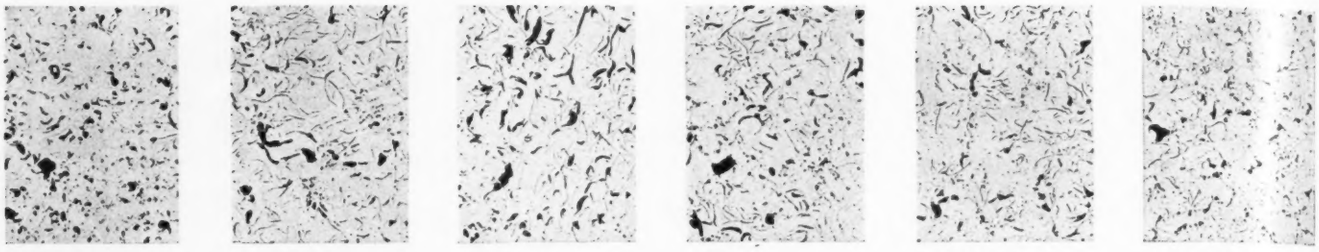
Superheated Irons

In Fig. 2 are shown the properties of two high-frequency furnace cast irons made from pig iron, steel scrap, and ferroalloys superheated to different temperatures. The irons were untreated in the ladle. There is a slow rise in strength with increased temperature at the low end of the temperature scale followed by an abrupt drop in strength, reaching a minimum at around 2,750 deg. F., and then another slow rise in strength as the temperature is further increased. This peculiar behavior in the strength as a

Table I—Damping Capacities of Several Plain and Alloyed Cast Irons

At Stresses Equivalent to 15 and 35 per cent of the Tensile Strength

Chemical Composition (per cent)							Tensile Strength, (lb. per sq. in.)	Per Cent Damping Capacity Stresses Equal to	
C	Si	Mn	S	P	Cu	Ni		15% T.S.	35% T.S.
3.37	1.00	0.52	0.10	0.22			40,500	9.9	23.4
3.16	1.54	0.57	0.11	0.22			48,500	9.0	21.3
2.90	1.57	0.57	0.10	0.21			55,500	7.2	19.0
3.12	1.55	0.53	0.10	0.22		1.0	47,500	9.8	18.3
3.16	1.63	0.54	0.10	0.22		2.01	49,000	11.9	21.7
3.13	1.50	0.55	0.10	0.22	0.97	0.98	56,500	10.5	18.7



0.018 per cent S | 0.024 per cent S | 0.076 per cent S | 0.161 per cent S | 0.250 per cent S | 0.294 per cent S

Fig. 5—Influence of sulphur on the size of graphite in cast iron

result of superheating can be readily followed from the structural changes in the iron; rather marked changes in the structure accompany the changes in properties.

In Fig. 3 are shown properties of similar irons heated over the same temperature range but treated in the ladle with ferrosilicon and with calcium silicide. In contrast to the untreated irons, the structure of the treated iron is fully pearlitic and contains no graphite in the dendritic (tree-like) pattern. The size of the graphite flakes decreases somewhat with increase in metal temperature. That probably accounts for the unusual effect of metal temperature on properties. Provided ladle additions can be employed, metal heating temperature sometimes influences strength more than do most alloy additions. In this case the tensile strength of the treated iron is raised from 35,000 to 51,000 lb. per sq.in. by means of metal temperature alone.

The problem is to explain why cast iron is so sensitive to metal temperature and to other factors in its manufacture. Why are ladle additions so effective at times? It can be rightly said that all of this is still an air-tight mystery to us, although with several individuals and laboratories studying the problem it may not remain a mystery much longer. When it is solved we can then begin to apply reasoning instead of rule of thumb methods when specifying operations for melting gray iron so as to produce certain results.

Boyles at Battelle has worked on various phases of the problem for the past four years. The ground covered in his researches has been wide; nevertheless there is still an enormous amount of work to do.

Effects of Sulphur

One important result of Boyles' work that is of general interest was his establishment of the fact that sulphur has a profound influence upon maintaining the proper structure in the iron. Boyles showed that in the absence of sulphur the graphite tends to separate in dendritic (tree-like) form giving the iron poor mechanical properties. The structure of a sulphur-free iron is shown in Fig. 4. On increasing the sulphur content of this grade of iron the graphite becomes flake-like in form. As shown in Fig. 5, the flakes increase in size with increasing sulphur, finally reaching a maximum beyond which their size decreases with increase in the percentage of sulphur.

Only a minimum of heat-treating is now being done on cast iron but certain developments are in progress that are likely to alter profoundly our attitude towards heat-treated iron. We can look forward to the time when each progressive gray iron foundry supplying a variety of castings to the trade will have its heat-treating department or will be obliged to send out certain of its work for heat-treatment.

One trend in gray iron foundry practice has been the use of greater percentages of steel and scrap in cupola charges in order to lower the carbon content and to make stronger irons. There has been a definite improvement in the pig iron in the last few years through the introduction of the smaller pig, a closer classification according to silicon, and greater uniformity in analysis of the pig in each carload lot which has been made possible by the use of large mixers at the blast furnace. These changes in pig and in proportioning of the cupola charge tend toward better control of the analysis of the cast iron and allow the foundrymen much greater leeway in the range of analyses that can be furnished.

Better Foundry Controls

Auxiliary equipment for the cupola has been vastly improved. Hot-blast cupolas are being installed in some of the larger foundries to reduce the amount of coke per charge, to get hotter iron, and to lower the cost of melting.

It is only recently that attempts have been made to control accurately the quantity of air so as to maintain a constant stage of cumbustion within the fusion zone in the cupola. Controlled combustion can be a definite source of fuel economy. Combustion within a cupola is almost entirely dependent upon the type and quantity of coke available in the combustion zone together with the amount of air used to burn it. A new control device measures the relative amount of air entering the cupola and simultaneously records the carbon dioxide content of the effluent gases. These two measurements are properly co-ordinated into an automatic control device consisting of a differential pressure recorder and a carbon dioxide recorder that regulates the blast so as to compensate for changing conditions in the combustion zone and to obtain both uniform and efficient cupola operation.

One more recent development should be mentioned. Cement bonded sand is now coming into use for molds for casting gray iron, steel and non-ferrous metals. The Randupson process, as the cement molding process is known, uses silica sand bonded with ordinary Portland cement and water. The amount of water added is such that the cement is subhydrated only. The cement proportions vary from 3 to 15 per cent, while the total water in the mixture is from 2 to 9 per cent. The sand is milled for several minutes and, because of its setting characteristics, must be used within a few hours after being mixed. The molding practice departs from usual practices as the material is rammed around patterns mounted in wooden boxes, and the molds are then set aside, after stripping off the boxes, to harden for from 24 to 72 hr. Their surfaces are blackened, if necessary. The various parts are clamped together without any surrounding flask parts.

The molds have great mechanical strength and high permeability. It is essential to preserve a well-defined ratio between the amount of water used and the quantity of cement in order to insure high permeability.

At the present time large tonnages of carbon and alloy steels, cast iron, gunmetal, phosphor bronze, manganese bronze, aluminum alloys, and magnesium alloys are being cast abroad by the Randupson process and in weights from a few pounds to 30 or 40 tons. The process is also making headway in this country.

The cement bonding of molding sand has been the first major step away from the customary methods of preparing sand mixtures. The future for the cement molding process appears to be exceedingly bright.

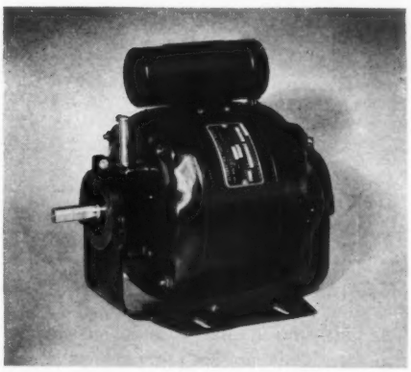
CAPACITOR MOTORS

Types, Characteristics and Fields of Application

C. T. BUTTON, *Sales Engineer*
The Holtzer-Cabot Electric Company

SQUIRREL-CAGE induction motors are nearly ideal for converting electrical to mechanical energy. as built for two or three phase circuits, the only mechanically wearing parts are the bearings. The conductors that are connected to the line, namely the stator windings, are all stationary, and the rotor, which is of the squirrel-cage type, is an extremely durable and trouble-free solid mass consisting of a laminated iron core with heavy bars short circuited by end rings. The rotating field produced by the stator induces low voltage current in the rotor bars, and torque results from the reaction of the rotor currents with the rotating magnetic field of the stator. Thus the rotor tries to catch up with the rotating field but never quite does. If it did there would be no induced current in the rotor and hence torque would be zero.

With a simple single phase stator winding there is no rotating field when the rotor is at standstill and hence there is no starting torque. A second winding is therefore put on the stator and a capacitor connected in series with it and the line as shown in Fig. 1. The capacitor causes the phase angle of the current in this second winding to advance. Thus, the ampere-turns in the two windings being out of step both in space and time, a revolving field results and torque is created. This simple form of capacitor motor is the nearest approach we have to the polyphase squirrel cage induction motor and hence the nearest thing to an ideal single phase motor.



Capacitor motor with capacitor mounted on top of the frame

Single Value Capacitor Motor

The simple type of capacitor motor has many advantages in addition to possessing the practical advantage of the polyphase squirrel cage type. It is the most quiet and has the best power factor and efficiency of any of the various classifications of single phase motors of comparable standards of design. But the simple capacitor motor has one inherent limitation, namely, low starting torque. However, by methods which will be described, large values of starting torque and various other modified characteristics can be secured.

The single value capacitor motor is also generally known as a permanent split capacitor motor or a low torque capacitor motor.

To obtain a high starting torque requires a high value of capacity, but with a large capacitor the electrical losses when running become excessive. Hence, in general the permanent split capacitor motor cannot have a high starting torque —usually considerably less than 50 per cent full load torque. Such motors in fractional sizes have capacitors in the range of about 1 to 15 microfarads. The starting current is relatively low, ranging from two to three times the full load current. The maximum or breakdown torque is usually at least twice the full load torque, as shown in Fig. 2. The efficiency and power factor of the single value capacitor motor are inherently high and the absence of a centrifugal switch and brushes makes this a quiet, simple, dependable motor. It is inherently quiet while running because the capacitor winding reduces the double frequency torque pulsation which is the cause of much of the noise in a single phase motor. Resilient mountings also are used to eliminate transmission of motor hum.

Low starting torque permanent-split

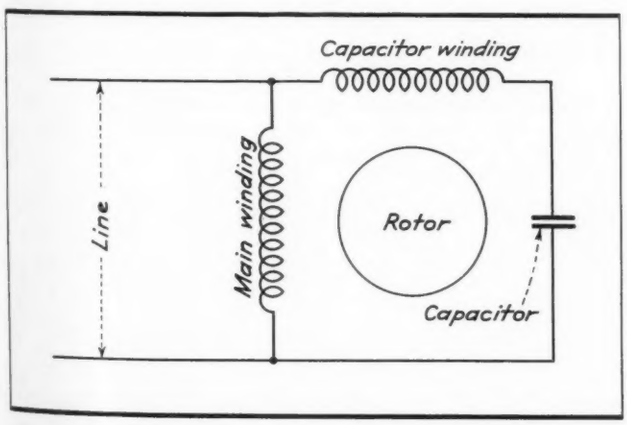


Fig. 1—Schematic wiring diagram of single value capacitor motor

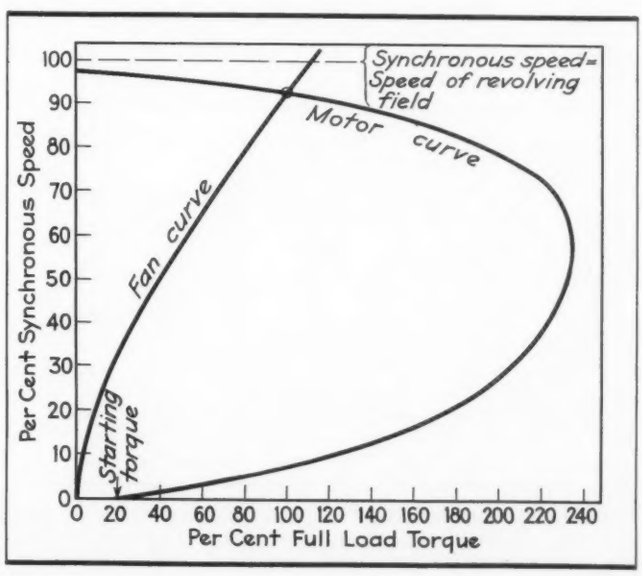


Fig. 2—Torque-speed characteristics of the capacitor type fan motor. The full running speed is where the torque-speed curves of fan and motor intersect

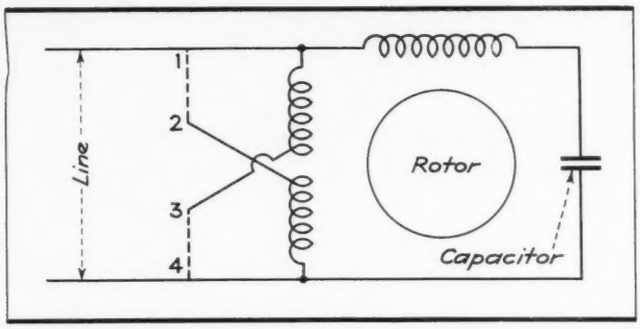


Fig. 3—Two-speed capacitor motor. High speed connection is with the two sections of main winding in parallel as shown by dotted lines. For low speed, leads 2 and 3 are together, putting the two main winding sections in series and thereby giving a low speed about two thirds that of high speed

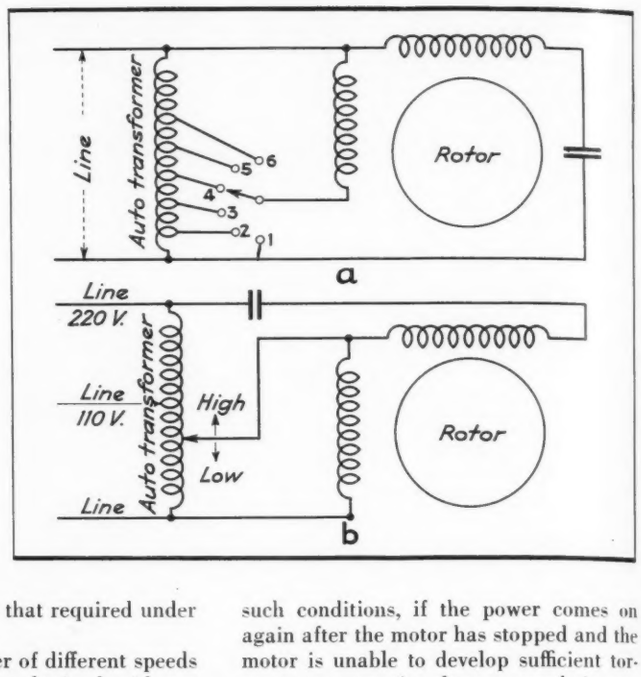


Fig. 4—Alternate schemes for auto transformer control for multi-speed fan motor. Starting torque decreases with decreased running speed

capacitor motors are ideal for driving fans and blowers and for any other applications where the load at starting is limited to the motor bearing friction. They are admirably suited for driving ventilating fans mounted on the motor shaft, small centrifugal pumps, grinding wheels and similar units where there is no imposed load at zero speed other than inertia. Fig. 2 shows the torque-speed characteristics of a fan and its driving motor. The running torque and running speed are determined by the point at which the two curves cross.

As noted on the curves, the motor must be designed so that at zero speed it will develop enough torque to overcome starting resistance. If the motor fails to start and remains across the line it will sooner or later burn out. Often the motor has a thermostatic switch to disconnect it from the line if it gets too hot.

In determining the required starting torque, allowances must be made for all possible conditions that might increase it. Cold or tight bearings, poor lubrication, low voltage and similar conditions require the motor to have a good margin of starting torque above that required under normal conditions.

Any desired number of different speeds with fan load can be obtained with capacitor motors, ranging from the normal speed down to 40 to 50 per cent of synchronous speed. Two speeds are obtained merely by a two position switch that changes two-sections of the main winding from parallel to series connection as shown in Fig. 3. Any number of additional speeds are obtained by a multiple position switch that connects to different leads on an auto-transformer, thereby varying the voltage applied across the main winding as shown in Fig. 4. The starting torque for any setting decreases with decreased running speed.

It is good design and application engineering to have the multi-speed motor capable of exerting sufficient starting torque at the lowest speed. The switch is quite commonly connected so that the first point is for highest speed which gives highest starting torque. This, however, does not protect the motor if there is a momentary shut down of power while the motor is running at lowest speed. Under such conditions, if the power comes on again after the motor has stopped and the motor is unable to develop sufficient torque to start at its slowest speed, it may burn out.

The accompanying torque-speed curves, Fig. 5, of a typical multi-speed capacitor type motor show how the torque decreases with decreased speed, the reduced fan speed being obtained by increased motor slip. The fan load-speed curve must be known in order that the motor can be designed to give the particular low speed desired. The torque required by a fan varies as the square of the speed, which is what makes the load ideal for this type of motor. Variable resistance is sometimes used instead of a transformer for speed control, but the efficiency is poorer on low speed as shown in Fig. 6 wherein the power consumption for the two types of speed control is compared.

Multi-speed motors may be obtained with 3-speed, 6-speed, or 10-speed switches in the controller. Some types of controllers utilize a toroidal wound auto-transformer of the slide-wire type, giving

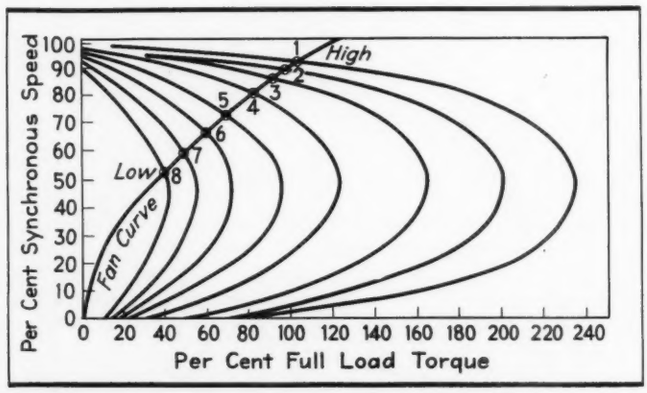


Fig. 5—Speed-torque characteristics of multi-speed capacitor type fan motor. The starting torque decreases with decreased running speed and at lowest speed should be enough to start the motor

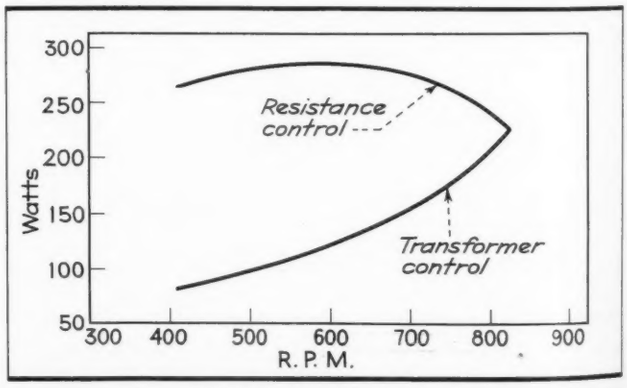


Fig. 6—Speed control by variable resistance instead of transformer gives low efficiency on reduced speeds as shown by these power consumption curves

in effect an infinite number of speeds down to the practical minimum of 40 to 50 per cent synchronous speed.

It is standard practice to mount the capacitor on the motor. The latter may then be used as a single speed motor; or with a snap switch as a two speed motor; or with a separate controller for multi-speed operation.

Of course special designs may be obtained where quantities warrant, such as double-shaft motors for driving two centrifugal fans, controllers mounted on motor, and so on. Adjustable speed motors for belted fans present a special problem which should be referred to the motor manufacturer for recommendation.

High Starting Torque Motors for General Purpose Application

Capacitor Start Induction Run Motor

For high starting torque capacitor type motors, a high value capacitor is used and by means of a centrifugal switch the capacitor winding is automatically disconnected at about 75 per cent full running speed. This is analogous to the common split phase motor, except that the capacitor in series with the capacitor winding increases starting torque per ampere, for which reason larger size single phase motors are practical in applications where the split phase type would draw excessive starting current. In order to obtain a high value of capacitance in a small space, an electrolytic type capacitor of the order of 100 to 400 mfd. capacitance is used. When the motor is running with the capacitor disnected it operates as, and has the characteristics of, a conventional split phase induction motor.

The limitation in the application of the high-capacitance high starting torque motor centers in the electrolytic condenser which will get hot and deteriorate

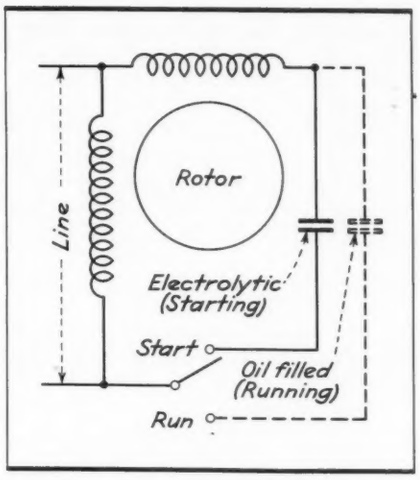


Fig. 7—High torque capacitor motor. The motor starts with the high capacity electrolytic capacitor in the circuit and at 75 per cent running speed the centrifugal switch cuts out this capacitor. The motor may then run as an induction run type, or the design of the motor may be such that the centrifugal switch connects into the circuit an oil-filled low value capacitor, shown dotted

if starting is too frequent, if the period of starting during which the condenser remains across the line is too long or if the motor operates in a high ambient temperature. Permissible frequency of starting usually is 20 starts per hr., each start not over 3 sec. duration. Maximum ambient temperature for the capacitor is 130 deg. F. The starting torque exerted by the motor should be sufficiently high so that the motor will reach 75 per cent of its running speed in a relatively short time. Or conversely the starting load and inertia or WR^2 should be kept within suitable limits for a given motor, with the same objective.

The capacitor start motor has found a wide field of application for such duty as domestic refrigerators, pumps and so on, because it is inherently inexpensive in construction and has 300 to 400 per cent of full load torque on starting.

Capacitor Start Capacitor Run Motor

The motor just described may be improved in respect to running performance by having a relatively small value of capacitance connected in series with the quadrature or capacitor winding while running, as shown in Fig. 7. The running capacitor may be left permanently connected in series with the capacitor winding, thus adding to the effective starting capacitance. This provides the operating advantages of the simple type of capacitor motor, namely, quietness, efficiency and high power factor, and frequently is utilized to increase the permissible rating of a given frame size.

A variation of the capacitor-start capacitor-run type is shown by Fig. 8 and its speed-torque curve in Fig. 9. In this capacitor-transformer type of high torque motor, the two optimum values of capacitance for starting and running are obtained effectively by taps on a small auto-transformer. This in effect changes the voltage on the capacitor, so that the leading volt-amperes are relatively high at the start, but are reduced to proper value for the running condition. This construction is commonly used on large sizes or where the starting conditions may be particularly severe—such as high inertia loads, frequent starting, or high ambient temperature. An oil filled capacitor is used.

Either of the two general types just described are referred to as two-value capacitor, or capacitor-start capacitor-run motors.

Conclusions

It is seen that the capacitor type motor is a versatile machine. It may be designed for almost any type of load. The cost is

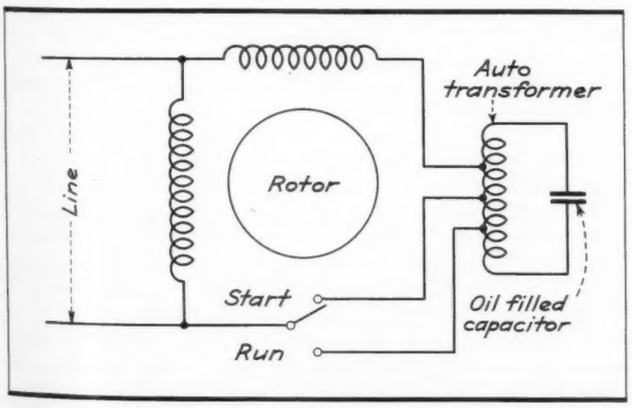


Fig. 8—Capacitor-transformer type of high starting torque capacitor motor secures optimum effective values of capacitance for starting and for running by using a small auto-transformer

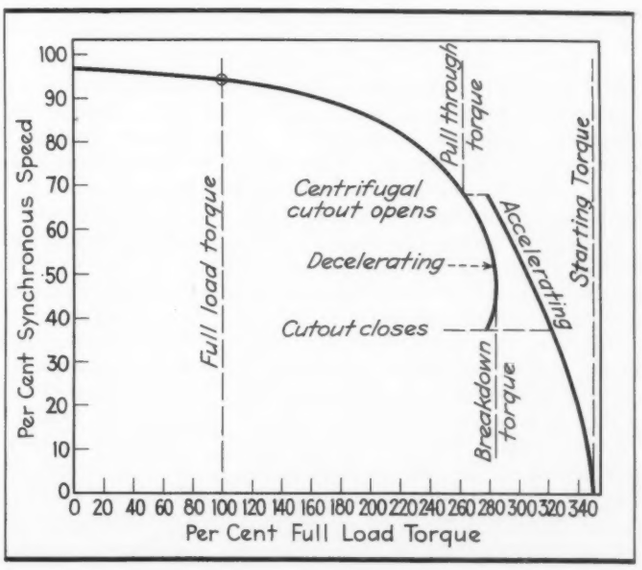


Fig. 9—Typical speed-torque curve of the high-torque capacitor motor of the transformer-capacitor type

relatively low. As compared with the repulsion-induction motor, it has comparable or superior performance.

One might say that the existence of any single phase motor is not justified if three phase or two phase, a.c. supply were universally available, but such a statement is not a realistic consideration of conditions.

The great improvement and reduction in cost and size of capacitors in the last 15 years has contributed greatly to the widespread use of capacitor motors.

This discussion is not to be regarded as a reference work for details of construction, but merely as an outline of basic principles. For example, many capacitor motors are made dual voltage, reversible, and with special characteristics and connections for special purposes. Progress in design and construction has been rapidly advancing in the last decade and there is no reason for supposing that a static level has been reached. On the other hand, the basic principles outlined herein are in large part relatively old—the names of Dr. Steinmetz and Professor Bailey are associated with early theoretical and practical investigation of the possibilities of the capacitor motor.

Case Histories In Patent Law

H. A. TOULMIN, JR.

EDITOR'S NOTE: *We wish to emphasize that in consenting to furnish this column wherein general explanations of the law in specific patent cases are set forth, Col. H. A. Toulmin, Jr., wants it clearly understood "that each actual case should be submitted to your own patent attorney who is the only one familiar enough to advise you accurately." The purpose of these explanations is to give a better understanding of questions of patent law.*)

No. 16

QUESTION: How much time does an inventor have before he has to file his application?

ANSWER: For many years the inventor was given two years within which to file his application for a patent. Last year a statute was passed changing this period from two years to one year. This one year statute goes into effect in August, 1940.

The year begins to run from the date of the first public use or sale or offer to sell. The year does not begin to run until one of those three events occur which constitute a disclosure to the public. The invention may be conceived, drawings made and extensive tests made privately, but if there is a public use of the invention or a sale of it or even an offer to sell it, then the one year will begin to run.

Another turn of the law which must be observed is that if the machine or process is kept secret either the sale of a product made by the process or the machine will be the same as a prior public use or sale.

Many courts have held that necessary public use in order to conduct experimental work over a considerable period will not constitute such prior public use as to cause the statutory period to run against the inventor on the theory that if the only way such tests can be made as in the case of a pavement, must necessarily be a public test, and the time for determining whether the pavement would last, would be more than the statutory period, then this period does not start to run until the successful completion of the tests. In every case there is a matter of fact to be determined as to what is just.

Of course, the only safe rule to follow is to file the patent application as promptly as possible in the Patent Office because that eliminates every question. On this subject of public use, the Supreme Court said in the case of Smith v. Sprague, 123 U. S. 248, 258:—

"But if the inventor allows his machine to be used by other persons generally either with or without compensation, or if it is, with his consent, put on sale for such use, then it will be in public use and on public sale within the meaning of the law."

In the case of an offer to sell, the Court of Appeals in the case of Wende v. Horine, 225 F. 501, 505, said:—

"If Horine's letter amounted to an offer to sell the apparatus, then clearly these letters, standing alone, put it 'on sale' within the meaning of the Statute to the only immediate prospective customer just as effectively as a distributed price list puts an article on sale to the public.

"The offer to the Stock Yards Co. was completed at the latest when Denison, as secretary, received the letters; the date at which he caused the substance of their contents to be communicated verbally to Sherman is immaterial, and, of course, the delay of over nine months before Horine's proposition, modified in some respects, was finally accepted, can have no bearing on the case.

"The Statute does not require a 'sale,' but only a placing 'on sale,' prior to two years before the application. Under this language, a completed sale, either with or without delivery, is not demanded; an offer to sell, made to a prospective purchaser after the experimental stage has been passed, the invention reduced to practice and the apparatus manufactured in its perfected form, is a placing on sale within the Statute."

On the subject of the prior public use the Supreme Court in the case of Woodbridge v. United States, 263 U. S. 50, 56, said:

"The importance of working out the purpose of Congress of keeping the inventor's monopoly within the term for which the patent is granted, is thus shown to be capital. Any practice by the inventor and applicant for a patent through which he deliberately and without excuse postpones beyond the date of the actual invention, the beginning of the term of his monopoly, and thus puts off the free public enjoyment of the useful invention, is an evasion of the Statute and defeats its benevolent aim."

On the subject of whether an inventor is justified in delaying more than two years after he makes his invention before he files his application, the courts generally resolve all doubts against the inventor as it is the policy of the law to encourage the inventor to file his application and ultimately to make a prompt disclosure to the general public through his patent.

In the case of Eclipse Machine Co. et al. v. Harley-Davidson Motor Co. et al., 252 F. 805, 811 (C.C.A. 3) the Court of Appeals for the Third Circuit said:

"When more than two years elapse after the invention is made, the inventor must assume the burden of excusing the delay and overcoming the presumption of dedication from commercial use."

Of course, one must be very careful not to make any publication which is more than the statutory period because this will bar his getting a patent. This was pointed out in Wagner v. Mecanno, Ltd., 246 F. 603, 607, as follows:

"An inventor's own publication of the device for which he seeks a patent more than two years prior to the application is a disclosure within Rev. St. 4886 (Comp. St. 1916, Sec. 9430) and precludes the patenting of his invention."

In conclusion, the rule is that no public disclosure should be made until that is absolutely necessary and then the application should be filed in the Patent Office within one year from the date of first such disclosure to the general public, whether this be accomplished by means of a publication, a public demonstration or use, a sale or an offer to sell.

PRODUCT FINISHES—II

Causes and Remedies for Finishing Troubles

GORDON H. ROBERTSON
Sherwin-Williams Company

IT IS advantageous for the product engineer to be able to analyze common causes for failures in finishes and to suggest remedies that may be helpful, since the specification of the correct finish does not always insure its proper application. The following tabulation is continued from the April number of PRODUCT ENGINEERING, pages 163 and 164. In the preceding installment, the importance of both surface cleaning and the choice of the proper reducer was stressed. The article covered "breaking" and skinning of liquid, excessive setting and sagging film. This article discusses lack of flow, "washing" of film, drying, lack of adhesion, flat spots, excessive body and other finish troubles.

5. Lack of Flow

CAUSE	REMEDY
A. Insufficient reduction.	A. Reduce according to instructions.
B. Use of solvent with too fast an evaporation rate.	B. If fast evaporation is due to local weather conditions, choose a slower evaporating solvent than originally recommended.
C. Improper atomization of spray gun.	C. Adjust spray equipment.
D. Application of too thin a film.	D. Apply more material to surface.
E. Excessive heat or cold.	E. Establish normal temperature close to 75 deg. F. of both material and room.

6. "Washing" of Film

CAUSE	REMEDY
A. In some dip operations, faulty ventilation in the hood above the dip tank allows a concentrated collection of solvent vapors which reduces the film on the object which has just been withdrawn from the dip tank, thereby causing the film to wash or flow off the coated surface.	A. Provide proper ventilation over dip tank.
B. Faulty ventilation in oven causes concentration of vapor.	B. Provide proper ventilation.
C. Wash caused by cleaning solvents or grease remaining in crevices.	C. Be sure surface is clean and dry, as well as all crevices. Preheat to evaporate thinners or burn off grease, if necessary.

7. Non Drying or Poor Drying

CAUSE	REMEDY
A. Humid weather.	A. If possible, place in heated drying room.
B. Cold weather.	B. Maintain a temperature of at least 65 deg.; 75 deg. is desirable for normal drying.
C. Absorption of drier by paint material.	C. While it is a problem of formulation to avoid possibility of drier absorption, there are occasions when the best formulated products are apt to face the difficulty. Remedy is to add drier in small quantities. It is best to consult the finish supplier for specific handling recommendations.
D. Greasy, waxy, or otherwise unclean paint surface.	D. Clean surface carefully with volatile solvents. If metal, use special metal treatment such as tabulated above.
E. Failure to stir all pigment of pigmented finishes into proper suspension before application. Failure to stir properly unbalances formula of applied material and often will cause poor drying.	E. Stir it again!
F. If application is over a stained surface, there may be some dye in the stain which tends to prohibit drying.	F. Use the proper stain, or seal stain for subsequent coats.
G. Improper ventilation.	G. Provide ventilation.
H. An attempt to fill rough wood or metal by applying a heavy coat retards thorough drying.	H. Do not attempt to use finish coat as a surfacer. Apply only a full covering coat.
I. Improper solvents.	I. Too fast evaporating solvent may cause surface drying and may entrap solvent.

(*Continued on next page*)

8. Spotty Drying

Cause	Remedy
A. Unclean surface.	A. Clean carefully with volatile solvent or if metal, with a commercial metal cleaner, such as tabulated above.
B. Unevenness of surface on metal or wood.	B. Seal to prevent porous areas from absorbing finish.

9. Lack of Hiding Power

Cause	Remedy
A. Over-reduction.	A. Add fresh, unreduced material to that which has been reduced.
B. Application on very cold, smooth surface which tends to cause film to flow off.	B. Use a faster evaporating solvent. See section on Industrial Reducers at beginning of this article.
C. Pigment not properly stirred into suspension.	C. Stir it and keep stirred.
D. Too slow evaporating solvent causing too much flow.	D. Use faster solvent.
E. Improper atomization.	E. Adjust spray equipment.

10. Lack of Adhesion

Cause	Remedy
A. Certain types of metal such as galvanized iron, cadmium, zinc are difficult surfaces.	A. If normal methods of metal preparation do not overcome adhesion difficulties, then send full particulars, along with samples of metal, to the finish manufacturer.
B. Unclean surface.	B. Clean carefully with volatile solvent, or if metal, with a commercial metal cleaner.
C. Lack of film toughness, produced by over-addition of drier.	C. Check results against fresh material to which no drier has been added.
D. Mar-proofer in previous finish or in first coat.	D. If refinishing over mar-proofed old finish, clean carefully with strong volatile solvent. If mar-proofer is in the first coat just applied, it will be necessary to choose another type of undercoater or else a mar-proof finish which will allow application of another coat over it without loss of adhesion.
E. Sometimes the finish coat and the primer used are not meant to be used together, and the solvent in the finish coat practically lifts the primer from the surface. Even though film will dry and have good appearance, primary adhesion has been ruined.	E. Make sure that the proper recommended primer and finish coat are used together.
F. Overbaking, which accelerates loss of flexibility in the film.	F. Check oven and bake according to instructions.

11. Lack of Adhesion Between Coats

Cause	Remedy
A. Primer and enamel not recommended for use together.	A. Use properly recommended system.
B. Primer dries too hard either due to inherent drying quality, or long aging prior to application of finish coat.	B. Roughen primer with sandpaper or steel wool. It may even be necessary to use a reducer of higher solvent strength in the finish coat in order that a " tooth " can be obtained in the primer film.
C. Grease from metal may sweat through to primer surface.	C. Proper metal cleaning and follow " B " above.

12. Brittleness

It is often difficult to differentiate between " lack of adhesion " and " brittleness " in evaluating some film failures. Other than inherent brittleness or lack of adhesion in a finish, the cause for each complaint will be the same.

Cause	Remedy
A. Improper baking. If complete polymerization of film has not been effected, brittleness may follow.	A. Check oven operation and follow baking instructions.
B. Misuse of material; paint designed for one surface applied to dissimilar surface.	B. Follow Mfgrs. instructions. Use metal coating on metal not on wood, etc.
C. Excessive amount of drier added	C. Consult manufacturer of finishing material before making drier additions in any quantity.

13. *Flat Spots*

Cause	Remedy
A. An absorbent type putty has not been sealed in and, accordingly, causes top coat to strike in.	A. Seal the putty.
B. In some types of ovens, the temperatures may not be at all uniform, causing over-baking at some portions of the finished object.	B. Ventilate the oven and circulate the air within it. Have oven checked by competent engineer with accurate instruments.
C. There may be chemical substances upon the surface which would tend to dull the gloss. In the case of urea formaldehyde enamels, the action of trichlorethylene degreaser fumes causes flatting.	C. Make sure that surface is carefully cleaned before finishing. In case of fumes attaching film, remove the source of fumes from close contact with oven and provide proper ventilation.
D. Foul ovens.	D. Provide proper oven ventilation.
E. Slight wrinkle in spots caused by addition of too much drier.	E. Use less drier.
F. Oily or dirty surface.	F. Provide clean painting surface.
G. Certain types of metal, such as Galvanneal and terne plate may cause flatting in spots during baking operation.	G. The flat spots, resulting from improper pickling or other causes can usually be eliminated quickly by proper cleaning. See list of cleaners tabulated above.

14. *Too Much Spray Dust*

Cause	Remedy
A. Wrong solvent blend.	A. Usual remedy is to choose a slower evaporating thinner.
B. Excess spray pressure.	B. Reduce pressure.
C. Over-reduction of material.	C. Use less reduction. Add fresh material to that which has already been over-reduced.

15. *Excessive Body*

Cause	Remedy
A. Any material which will dry in the presence of air at normal temperatures will tend to take on body by virtue of the oxidation which takes place.	A. If bodying of the material has not proceeded to the point where there is livering action, it is often possible to bring the thickened particles back into solution by addition of a stronger solvent from the same solvent classification.
B. Even a straight baking type enamel will tend to take on additional body due to evaporation of solvents.	B. Add proper solvent to bring liquid to proper viscosity and body.
C. In the more advanced stages of oxidation, a livering action often occurs which is aggravated by the too swift addition of extra thinner. It should be remembered that thinner should always be added slowly and the mixture stirred at the same time.	C. If a definite livering has occurred, it is not easily feasible to reclaim the material.
D. Use of improper solvent.	D. Use recommended thinner.

General: The primary cause of excessive bodying is, in most cases, improper handling of dip tank or other storage facilities. All storage tanks should be kept tightly sealed.

16. *Cracking or Crazing of Film*

Cause	Remedy
A. Application of long-oil material over a very short one, or vice-versa.	A. Make sure that materials used comprise a definite approved system.
B. Application of too heavy coats.	B. Apply only sufficient material to accomplish full covering.
C. Due to foul gas in oven, cracking or dull gloss in baked film may result.	C. Ventilate oven properly.
D. Checking may be caused by sudden chilling of film during drying.	D. Raise temperature of drying room and avoid drafts which strike the work during drying.

17. *Excessive Marring*

Cause	Remedy
A. Film not completely dried.	A. Allow for more complete air-drying or baking.

Note: Use mar-proof quality if practical.

Table to be concluded in June PRODUCT ENGINEERING

One of the two drafting rooms at Pneumatic Scale Corporation, Limited. Fluorescent lighting is used over all drafting boards

ENGINEERING RECORDS

Drafting Room Methods; Use of Photography

GEORGE F. BURTON, *Assistant Chief Draftsman*
Pneumatic Scale Corporation, Limited

ONE of the perplexing problems in engineering departments is that of maintaining a complete and up-to-date file of drawings and bills of materials. This is particularly difficult for companies that manufacture special machinery to meet certain service conditions, as in the packaging and bottling field. Basic features of successive designs of a line of machines may be common to all although each model may differ in certain details. It is apparent then that complete visual records of successive designs will save much needless re-drafting of standardized assemblies.

Of probably greater importance is the use of a well-indexed blueprint file and a comprehensive, well-indexed photographic file as an aid when starting a new development. The designer can, after a study of these records, often develop new mechanisms from existing tested designs, minimizing the number of changes in patterns and machine parts, and saving much drafting time which might otherwise be wasted.

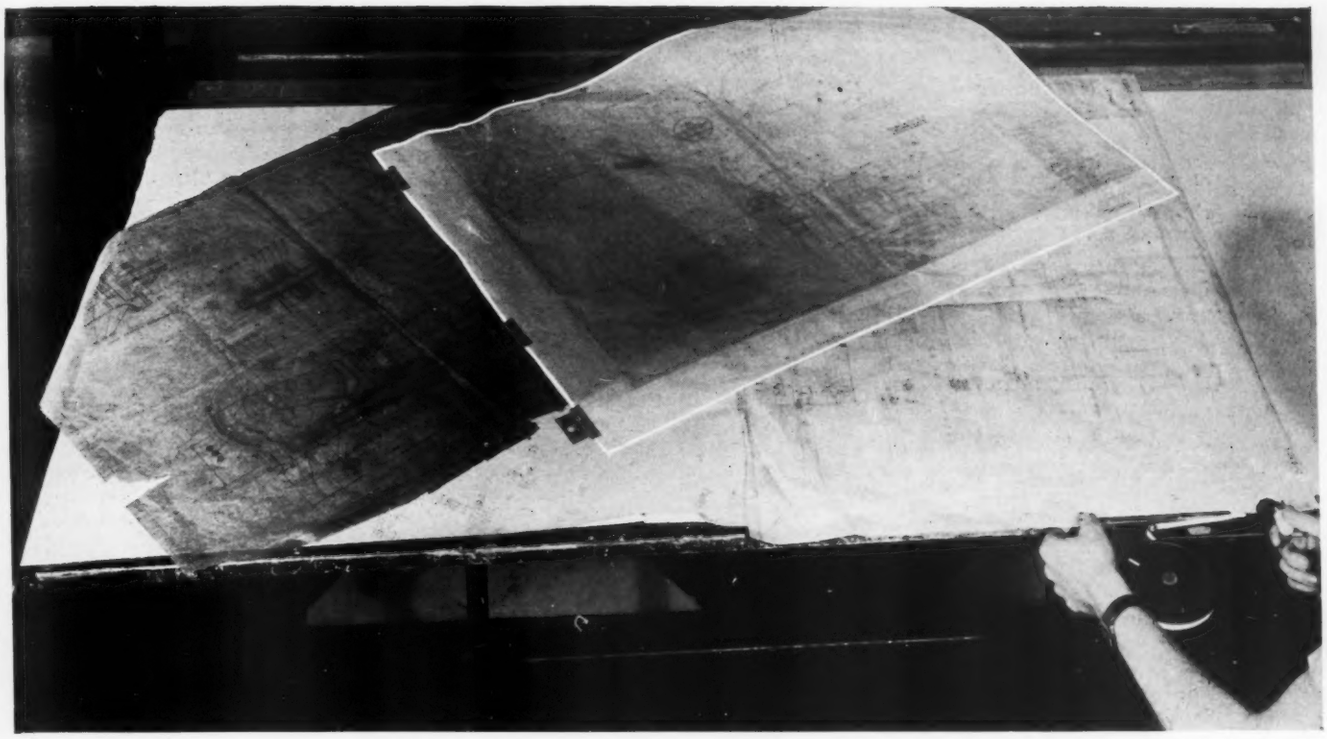
To meet these conditions, Pneumatic's drafting division has developed interesting techniques in the handling and filing of blueprints and in the maintenance of a complete engineering file on each new machine supplemented by detail photographs furnished through a well-organized photographic division.

Handling of Drawings

Original tracings after a number of years' use, tend to wear away in spots and to tear along the edges; this is particularly true of pencil drawings made on translucent paper. All original layout and detail drawings are made on tracing paper in pencil. When the machine has been tested and proved, and drawings are to be continually used, inked tracings are made. However, as the number of men available for this type of work is limited, many drawings are not traced but are used until they become badly worn.

Some of the original drawings in Pneumatic's files are very old; although they are pencil on translucent paper, they are still in use. When the drawing starts to wear, the worn parts are cut away and mended with self-sealing translucent cellulose tape. Then in order to strengthen the edges and prevent tearing, a unique edger is used to fold self-sealing white cellulose tape along the drawing edges. It has been found that this strengthening band will positively prevent edge tearing and add to the life of the drawing.

Strengthened edges can also be used to advantage on blueprints subject to rough handling in the shop. They have proved a further aid in filing, since the tabs by which large tracings are suspended



Worn tracings before and after mending with self-sealing translucent tape and edging with self-sealing white cellulose tape. Note the Minnesota edging applicator shown in the right hand corner being used to apply tape to a worn drawing

tended to tear through the edges of the sheet when the drawings are being removed and replaced in the vertical steel files in which originals are suspended.

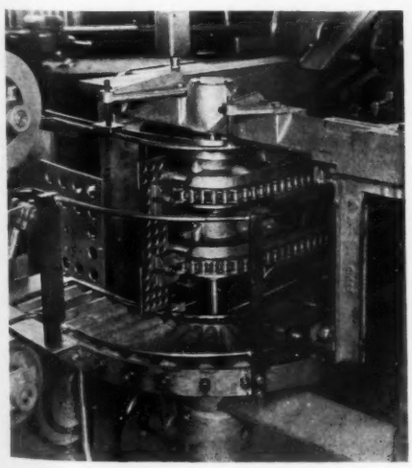
The edging tool which is used in the drafting room is a small Minnesota Mining and Manufacturing Company device that is temporarily attached to one of the drawing boards. The machine is loaded with a 30 ft. roll of self-sealing cellulose tape. The drawing is placed in the guideways and as the handle is turned the tape is fed forward and folded over the drawing edge. A small cutoff device severs the tape at the desired length. Cost of edging tracings by this method runs about ½ cent per foot.

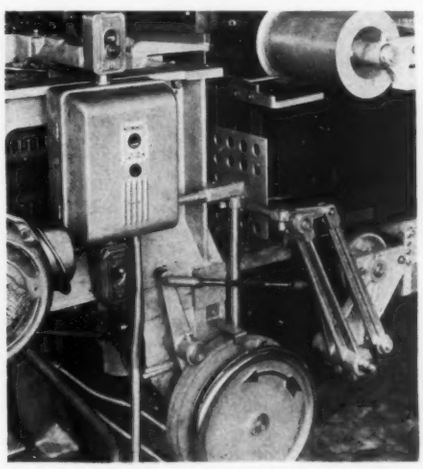
In making blueprints, it was a common occurrence that the operator's hands and arms developed a rash caused by the constant contact with the fixing water solution of potassium bichromate. This chemical also tended to stain the back of finished prints yellow. After some experimenting, it was found that peroxide of hydrogen diluted in water could be used instead of the potassium bichromate, giving much more contrast in the finished print. It also acts as a disinfectant and positively prevents infection of the operator's hands and arms.

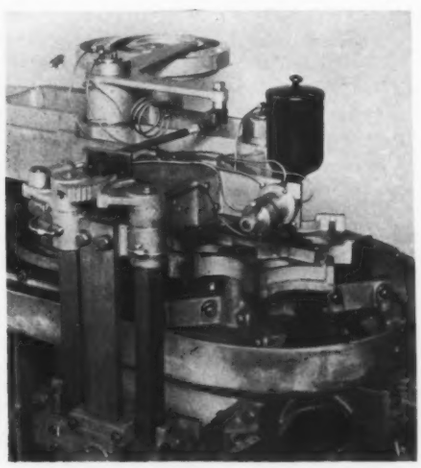
It is also of interest to note that the potassium attacked the fabric dryer belts; this does not occur when hydrogen peroxide is used. Of course, the most important advantage from the company's point of view is the saving of operator time previously lost on account of infection. After several months' use of this new wash, it has been found that cost of hydrogen peroxide is no greater than the previous chemical used.

White prints on translucent Ozalid paper are used to advantage as original tracings for new parts similar to existing parts. Minor changes are made directly on the finished Ozalid print using a liquid eradicator, and thus saving much drafting time particularly in complicated drawings where a relatively few number of changes must be made. In effect then the corrected white print becomes a "master." This system cannot be used when the original tracings are in bad

Close-ups of pusher device, discharge mechanism and a lubricating circuit as photographed for the engineering files







condition since dirt and fold marks tend to reproduce on the white print.

Photographic Records

As a visual aid to the designer a photographic file is kept along with the blueprint file. Photographs are taken of front, rear, sides and tops of the machine with all covers removed and are bound in a folder cross-indexed to the blueprint file on the machine. Thus at any time there are available to designers and draftsmen various views of the machines showing mechanisms and parts in place. As mentioned previously, this is of invaluable aid in starting out on a new design; it is also an aid to the draftsmen since parts can be seen in place and in proper relation to each other. Further, these photos can be numbered and used in a parts catalog.

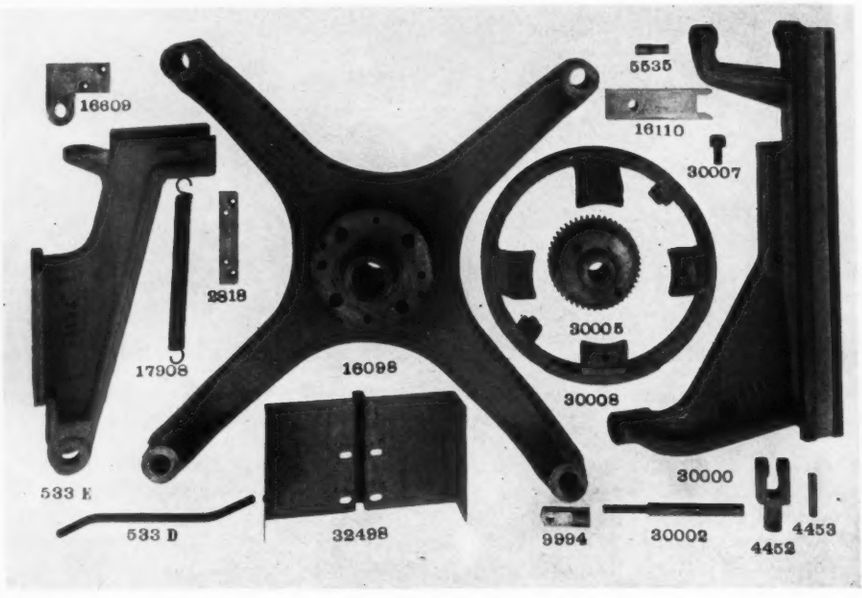
In order to operate this photographic system effectively, Pneumatic has set up a separate photographic department operating under the engineering division and equipped with various types of cameras and finishing apparatus. This department furnishes the engineering division with machine views and details, and the catalog department with breakdown views and parts views for the assembly catalogs sent out with each new machine. In many cases this photographic department also furnishes the advertising and sales departments with effective photographs. All illustrations for this article were made by Pneumatic's photo department at the plant, as a part of their routine work.

Sections of the machines are photographed for the engineering records with a small camera using 4 by 5 in. film. This is especially advantageous in cases where the original drawings are poor, or are very special, or where last minute changes have been made in the shop and are not indicated on the blueprints. This small camera is also useful for photographing electrical and lubricating circuits in place. These are later used in instruction books accompanying each machine.

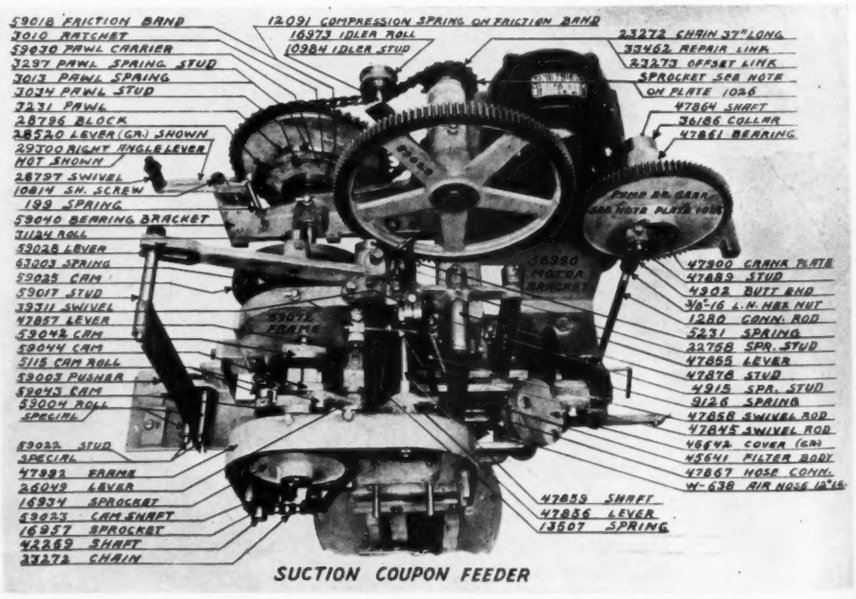
Several examples of the work done are shown in this article. For the catalog department, in addition to supplying overall assembly photographs, the department also supplies photographs of the dis-assembled machine parts in their proper relative positions so that the purchaser will have no trouble in recognizing a part when making a replacement order. Assembly drawings are photographed to aid the purchaser in assembly and dis-assembly of machine sections. These are taken in sections so that details can be read easily. However, it has been found that in cases where a number of copies are desirable, it is more economical to use planograph reproduction.

The overall control index of engineering photographs which is kept is made up of 8 by 10 in. glossy prints on which pertinent data as to machine, date of design and description is permanently attached to each numbered print. When changes in design are made, a definite procedure is followed to maintain up-to-date records. The designer notifies the drafting room head who makes the changes on the tracings and who, in turn, requests the photographic department to make a photograph of the new part or new assembly as the case may be. The new photograph is placed in the engineering file and a copy is entered in the photographic department's cross-indexed file. In this manner all engineering visual and paper records are kept up-to-date.

An intelligent use of photography as an aid in keeping engineering records has promoted efficiency in the design department and has resulted in considerable savings in drafting time and costs. The preservation of originals and the development of improved printing methods have also helped cut drafting room overhead considerably.



Machine parts are laid on a glass topped table in their proper relative positions and photographed from above for the parts catalog. Numbers are stamped on tape and placed under each part for identification. Shadows are avoided by using under-table illumination and diffused lighting



Referenced detail illustration for parts catalog. Photographed before final machine assembly, the parts are referenced with name and number by draftsman

CAM DESIGN ANALYSIS

With Formulas for Determining Cam Motion Factors

WADE H. SHORTER, JR.
United Shoe Machinery Corporation

INDUSTRY'S demands for increased speed in machines generally have been satisfied through the application of technical analysis to the design of machine elements, and also by means of continued improvement in manufacturing accuracy. An outstanding example of the results accomplished by the inseparable twins, engineering design and manufacturing accuracy, is in the performance of modern gears. Speeds readily obtainable today with gear drives were unheard of only a few years ago.

Some machine parts, however, among which the cam is notable, have not come in for enough attention, and consequently the performance limitations of cams are usually the factors which determine the maximum speeds of cam controlled machines.

For the operation of average machine cams the limiting speed range is 600 to 800 r.p.m. Few designers would attempt to develop a machine with the expectancy of obtaining more. If higher speeds are required link motions must be resorted to, although linkages are not as versatile as cams and being more complicated are usually more expensive.

The relatively low speeds at which the ordinary machine cam must operate is not unreasonable when the crude methods of cam designing and cutting are considered. Not much fundamental information to aid the designer in making a technical analysis of the cam problem is available, therefore he usually resorts to graphical constructions which are not conducive to a thorough understanding of the general factors involved in cam motions.

In the same category with design is the manufacturing of cams, since there is no commercial method for cutting the tracks with the same degree of accuracy readily obtained in other machine parts. With the exception of the instances where only a few are required most commercial cams are generated in machines which receive their control from a master cam or leader. The accuracy of the leader, therefore, determines the accuracy of the cam. The objection to this system lies in the difficulty of obtaining accurate leaders. Except for the harmonic type cam, which can now be generated, leaders are usually cut in milling machines by the step process from data which are either computed or, more often, measured from carefully made templates. In milling cams or leaders by step cutting it is difficult to obtain a smooth continuous cut regardless of the number of steps chosen, and finishing must be done by hand methods which further destroy the theoretical accuracy of the track.

Thus, it can be seen that the procedure for making cams today is in the same stage of development as that for gears previous to the widespread application of engineering design and accurate generating methods. The same processes of improvement to which the modern gear was subjected must be applied to cams if higher speeds are to be attained. This is all the more logical when it is considered that the gear is nothing more than a series of cams.

Most designers find that a technical analysis of any cam problem is not a waste of time. Some formulas and data that should be helpful in selecting a suitable cam to perform a desired motion will be presented for analyzing cam problems to an extent not possible by graphical methods.

In the majority of cam designs the designer is concerned only with moving the follower from one point to another in a specified time. The method of accomplishing this is not usually a design limitation, uniform and other special motion excepted as long as there is smoothness of action, reasonable loads in the mechanism, and a satisfactory life of the cam.

There are numerous types of base curves available from which the designer can select his cam, but probably because of the ease of construction, practice has narrowed the list to uniform motion, uniform acceleration or gravity, and harmonic base curves. Generally, uniform motion is used where machine movements require it; the gravity base is used where cam speeds are high to obtain minimum accelerations; and the har-

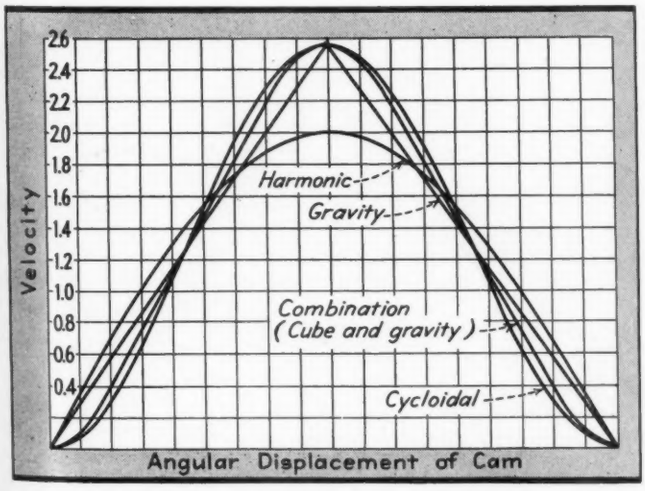


Fig. 1—Comparative velocity characteristics for cams with different types of base curves

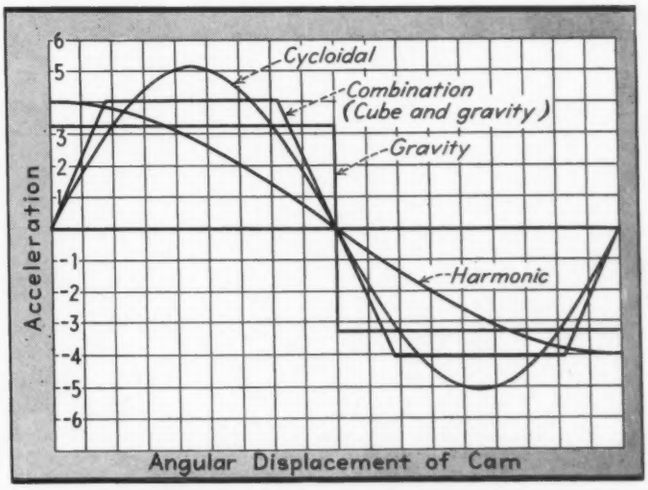
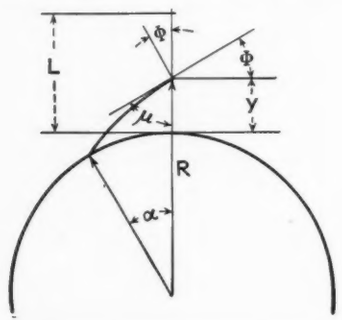


Fig. 2—Comparative acceleration characteristics for cams with different types of base curves

Table I—Cam With Radial Follower

Type	Uniform Velocity	Gravity		Cube		Harmonic $H = L/2$	Cycloidal
		Acceleration	*Deceleration	Acceleration	*Deceleration		
Y	$K\alpha$	$K\alpha^2$	$L - K\alpha^2$	$K\alpha^3$	$L - K\alpha^3$	$H - H \cos K\alpha$	$L(K\alpha - \sin K\alpha)/2\pi$
K	L/θ	$2L/\theta^2$	$2L/\theta^2$	$4L/\theta^3$	$-4L/\theta^3$	$180°/\theta$	$360°/\theta$
R	$r + K\alpha$	$r + K\alpha^2$	$r + L - K\alpha^2$	$r + K\alpha^3$	$r + L - K\alpha^3$	$r + H - H \cos K\alpha$	$r + L(K\alpha - \sin K\alpha)/2\pi$
Tan μ	$r/K + \alpha$	$R/2K\alpha$	$-R/2K\alpha$	$R/3K\alpha^2$	$-R/3K\alpha^2$	$R/K\,H \sin K\alpha$	$2\pi R/L(K - K \cos K\alpha)$
Φ	$90° - \mu$	$90° - \mu$	$90° - \mu$	$90° - \mu$	$90° - \mu$	$90° - \mu$	$90° - \mu$
$\frac{dR}{d\alpha}$	K	$2K\alpha$	$-2K\alpha$	$3K\alpha^2$	$-3K\alpha^2$	$K\,H \sin K\alpha$	$L(K - K \cos K\alpha)/2\pi$
$\frac{d^2R}{d\alpha^2}$	0	$2K$	$-2K$	$6K\alpha$	$-6K\alpha$	$K^2 H \cos K\alpha$	$LK^2 \sin K\alpha/2\pi$
Velocity of follower	$K\omega$	$2K\omega\alpha$	$-2K\omega\alpha$	$3K\omega\alpha^2$	$-3K\omega\alpha^2$	$K\,H\omega \sin K\alpha$	$L(K\omega - K\omega \cos K\alpha)/2\pi$
Acceleration of follower	∞ and 0	$2K\omega^2$	$-2K\omega^2$	$6K\omega^2\alpha$	$-6K\omega^2\alpha$	$K^2 H\omega^2 \cos K\alpha$	$LK^2\omega^2 \sin K\alpha/2\pi$
Position of maximum Φ	$\alpha = 0°$	$\frac{\theta}{2}$		$\frac{\theta}{2}$		$\cos K\alpha = \frac{H}{r + H}$	$\frac{2L(1 - \cos K\alpha)}{\sin K\alpha} = 2\pi r + LK\alpha$ †



* Sign of α for " Gravity " and " Cube " decelerations is negative
† Solve for α by trial
α = Any angular position of cam to give rise Y to follower
θ = Total angular turn of cam to give rise L to follower
r = Radius of base circle
R = Radius vector of center of follower
μ = Angle between tangent to curve and R
Φ = Pressure angle of cam
L = Rise of follower
ω = Angular velocity of cam

$$\text{Radius of curvature} = \frac{\left[R^2 + \left(\frac{dR}{d\alpha}\right)^2\right]^{\frac{3}{2}}}{R^2 - R\left(\frac{d^2R}{d\alpha^2}\right) + 2\left(\frac{dR}{d\alpha}\right)^2}$$

monic base is used for the average design to obtain the advantage of smooth cross-over and consequent minimized noise. While no one can question the simplicity and usefulness of the gravity and harmonic curves, they do not meet most advantageously all the conditions which the designer commonly encounters, especially where speeds are high and mechanisms start under relatively heavy loads. For these conditions the less known combination of cube and gravity, and also the cycloidal curves find their use.

The former curve combines the cube and gravity bases so that each half of the rise, acceleration and deceleration, is composed of a cube base for 1/10 of the total angular displacement of the cam, a gravity base for 3/10 of this displacement, and the gravity base modified by subtracting the cube base from it for the final 1/10 of the displacement. The cycloidal curve, so called for lack of a better term, is a form of modified harmonic, whose ordinates are the abscissas of a cycloid curve having a base equal to the rise of the follower. Both the combination and cycloidal cams are distinguished by their acceleration characteristics, which are favorable to high speed motions starting under load. A further comparison is shown in Figs. 1 and 2 by velocity and acceleration characteristics between these two cam curves and the two previously mentioned.

An analysis of the uniform motion, gravity, cube, harmonic, and cycloidal types of base curves has resulted in the formulas presented in Tables I, III and IV, which are suitable for use in designing radial cams with radial, offset-set, and swinging types of follower construction. The results may also be applied to develop formulas for designing barrel or cylindrical cams, but such formulas are not included in this article. These formulas, given in terms of the rise of the follower and angular displacement of the cam, enable the designer to determine at any point of the cam track these data:

Radius of the pitch surface, R
Pressure angle of the track, Φ
Radius of curvature of the track
Velocity imparted to the follower
Acceleration imparted to the follower

By determining R, the radius of the pitch surface of the cam at a number of equally spaced angular positions, the cam can be cut directly from computed data thus avoiding the use of templates or the necessity of accurately measuring laid-out designs. It should be noted that the data obtained for the swinging type followers are mathematically correct, a condition which is only approximated by a graphical construction.

Among the values depending on Φ, the pressure angle of the cam, are the bending stress in the follower mechanism, the normal load on the cam track, the torque required to turn the cam, and in a measure, the smoothness of operation of the cam. While 30 deg. is usually

given as the practical limiting value of this angle, it should be remembered that the greatest stresses do not necessarily occur where the pressure angle is maximum. In fact, it is quite possible that little or no load occurs at this position. Hence, the value of the maximum pressure angle does not always affect the design of the cam.

The formula for the radius of curvature of the track at any position is important first, in determining whether undercutting exists, and second, in determining the load transmitting capacity of the cam. To avoid undercutting the radius of the follower roll can be equal to, but in general should be less than, the shortest radius of curvature of the cam pitch surface when measured on the working surface side. The surface stress, and hence the load transmitting capacity of a cam, is a function of the radius of curvature of the track.

Use of the velocity and acceleration formulas for determining the character of the motion has already been explained, but these formulas are also necessary for computing mass and load effects of cam-driven mechanisms. It is important to remember that the total load to which the cam is subjected is the sum of the transmitted and acceleration loads, and that oftentimes the acceleration component is as great or greater than the transmitted component.

Determination of the load carrying capacity is as important in the design of cams as in any other machine element, though it is generally neglected. This value, as shown by the Hertz equation, is a function of the modulae of elasticity of the cam and the follower roll materials, radii of curvature of the contacting surfaces, and width of contact, and can be expressed by a formula in which

W_w = Maximum safe wear load
C = Wear load factor
F = Effective width of contact
R_1 = Radius of curvature of cam at point where loading is being considered
R_2 = Radius of cam roll

$$W_w = \frac{CF}{(1/R_1) + (1/R_2)} \qquad (1)$$

For information on the safe loading of cams, we are indebted to Earle Buckingham, Professor of Engineering Standards, Massachusetts Institute of Technology, and to G. J. Talbourdet, Research Engineer, United Shoe Machinery Corporation, who are conducting extensive research to determine the relationship between the surface stress and life of a cam; or in terms of Equation (1), to find values of the wear load factor C which will insure a cam turning a predetermined number of revolutions without failure.

It appears from recent tests that at least under pure rolling contact, cast iron and bronze have surface wear endurance limits, that is, the surfaces withstand wear indefinitely if the compressive stress is below a certain value. Steels, on the contrary, do not have a definite surface wear endurance limit and surface failure may occur at any load.

The C values or wear load factors shown in Table II, for cast iron and bronze materials are for computation of loads that insure the compressive stress being below the surface wear endurance limit. The factors for steel combinations, give C values for 300 million cycles. It should be understood, however, that these values apply only when pure rolling action exists between the cam and follower, since the resistance to wear decreases appreciably in proportion to the rate of sliding.

When using the formulas presented in Tables I, III and IV, it should be noted that:

1. In solving equations for the deceleration half of the gravity and cube curves, the origin is changed to the finishing end of the rise and values of α are assumed negative.

2. In the off-set and swinging types of follower construction, conditions are noted when the angle ϵ is either the sum or the difference of the angles α and γ. If the conditions are such that $\epsilon = \alpha + \gamma$ the equations for $d\epsilon/d\alpha$, $dR/d\epsilon$, $d^2R/d\alpha^2$, and $d^2\epsilon/d\alpha^2$ take the upper sign in the places where a plus and minus sign is given. If the conditions are the reverse and $\epsilon = \alpha - \gamma$ these same equations take the lower sign.

3. The solution of equations for the radius of curvature, for off-set and swinging follower constructions is tedious even with the aid of a calculating machine. It may be easier, for these types, to lay out the cam and measure the curvatures.

4. The equations for the radius of curvature give the radius of the pitch surface of the cam. The equations are to be used as presented when determining whether or not undercutting exists, but when used in the Hertz equation to determine the load carrying capacity of the cam the radius of the follower roll should be subtracted or added.

The method of deriving the K values, used in the cube and gravity formulas when designing the combination cam, is of interest.

Referring to Table I for cams having radial type followers, let

K = Constant of cube base curve
K_1 = Constant of gravity base curve
α = Any angular displacement on cube curve from its origin
α_1 = Any angular displacement on gravity curve from its origin
ρ = Any angular displacement on combination cam
L = Total rise of follower
θ = Total angular displacement of combination cam rise follower distance L

At point of joining, cube and gravity curves must be tangent. The formulas for velocities and accelerations are, therefore, equated and solved simultaneously to obtain the relationship between α and α_1, at the junction.

$$3K\omega\alpha^2 = 2K_1\omega\alpha_1$$
$$6K\omega^2\alpha = 2K_1\omega^2$$

From which is obtained $\alpha_1 = \alpha/2$, or the displacement on the cube curve from its origin is double that on the gravity curve at the point where the two are tangent.

Proportioning the total angular displacement, as described, into 1/10 cube, 3/10 gravity, and 1/10 gravity minus cube for each half of the total rise L

$$\frac{L}{2} = \left[K\alpha^3\right]_0^{\theta/10} + \left[K_1\alpha^2{}_1\right]_{\theta/20}^{9\theta/20} - \left[K\alpha^3\right]_0^{\theta/10}$$

From which $K = 25L/3\theta^3$ and $K_1 = 5L/2\theta^2$

These constants may be used in place of $4L/\theta^3$, and $2L/\theta^2$, respectively in the cube and gravity formulas for analyzing the combination cam.

It should be noted that when selecting angular increments on the combination cam, these angles must be measured from the origins of the cube and gravity curves before they can be used as α and α_1, in their respective formulas. For example, for values of ρ from 0 to $\theta/10$, α varies from 0 to $\theta/10$; for values of ρ from $\theta/10$ to $2\theta/5$, α_1 varies from $\theta/20$ to $7\theta/20$; for values of ρ from $2\theta/5$ to $\theta/2$, α_1 varies from $7\theta/20$ to $9\theta/20$ and α varies from 0 to $\theta/10$.

It should be emphasized here that the author does not wish to give the impression that the four types of base curves discussed are suitable to meet all cam designs. [*Editor's Note:* Table IV will appear in the June issue.]

Continued on next page

Table II—Wear Load Factors

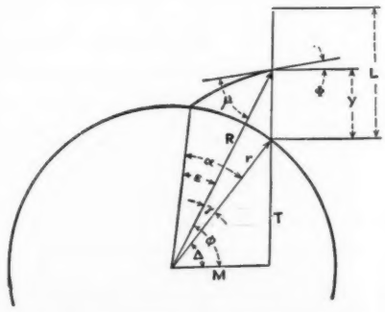
Materials	C
Hardened steel and cast iron	1,000
Hardened steel and nickel cast iron	2,000
Hardened steel and semi-steel	2,000
Hardened steel and No. 65 phosphor bronze	1,200
Hardened steel and No. 6150 chrome vanadium steel (Heat treated to 310–330 BHN)	1,500
Pack hardened steel and pack hardened steel (0.060 in. minimum depth of case)	6,000

Table III—Cam With Offset Follow

Type	Uniform Velocity	Gravity		Cube
		Acceleration	* Deceleration	Acceleration
Y	$K\alpha$	$K\alpha^2$	$L - K\alpha^2$	$K\alpha^3$
K	$\frac{L}{\theta}$	$\frac{2L}{\theta^2}$	$\frac{2L}{\theta^2}$	$\frac{4L}{\theta^3}$
D			$D = T + L$	
R	$\sqrt{r^2 + 2KT\alpha + K^2\alpha^2}$	$\sqrt{r^2 + 2KT\alpha^2 + K^2\alpha^4}$	$\sqrt{M^2 + D^2 - 2DK\alpha^2 + K^2\alpha^4}$	$\sqrt{r^2 + 2KT\alpha^3 + K^2\alpha^6}$
$\frac{dR}{d\alpha}$	$\frac{KT + K^2\alpha}{R}$	$\frac{2KT\alpha + 2K^2\alpha^3}{R}$	$\frac{2K^2\alpha^3 - 2DK\alpha}{R}$	$\frac{3KT\alpha^2 + 3K^2\alpha^5}{R}$
$\frac{d\epsilon}{d\alpha}$	$1 \pm \frac{KM}{R^2}$	$1 \pm \frac{2MK\alpha}{R^2}$	$1 \mp \frac{2MK\alpha}{R^2}$	$1 \pm \frac{3MK\alpha^2}{R^2}$
$\frac{dR}{d\epsilon}$	$\frac{RK(T + K\alpha)}{R^2 \pm KM}$	$\frac{(2KT\alpha + 2K^2\alpha^3)R}{R^2 \pm 2MK\alpha}$	$\frac{(2K^2\alpha^3 - 2DK\alpha)R}{R^2 \mp 2MK\alpha}$	$\frac{(3KT\alpha^2 + 3K^2\alpha^5)R}{R^2 \pm 3MK\alpha^2}$
$\frac{d^2R}{d\alpha^2}$	$\frac{K^2M^2}{R^3}$	$\frac{2K[R^2(T+3K\alpha^2) - 2K\alpha^2(T+K\alpha^2)^2]}{R^3}$	$\frac{2K[R^2(3K\alpha^2-D) - 2K\alpha^2(K\alpha^2-D)^2]}{R^3}$	$\frac{3K\alpha[R^2(2T+5K\alpha^3) - 3K\alpha^3(T+K$
$\frac{d^2\epsilon}{d\alpha^2}$	$\mp \frac{2K^2M(T + K\alpha)}{R^4}$	$\pm \frac{2MK[R^2 - 4K\alpha^2(T + K\alpha^2)]}{R^4}$	$\mp \frac{2MK[R^2 - 4K\alpha^2(K\alpha^2 - D)]}{R^4}$	$\pm \frac{6MK\alpha[R^2 - 3K\alpha^3(T +$
Tan μ	$\frac{R^2 \pm KM}{K(T + K\alpha)}$	$\frac{R^2 \pm 2MK\alpha}{2K\alpha(T + K\alpha^2)}$	$\frac{R^2 \mp 2MK\alpha}{2K\alpha(K\alpha^2 - D)}$	$\frac{R^2 \pm 3MK\alpha^2}{3K\alpha^2(T + K\alpha^3)}$
Φ	for $(\alpha-\gamma)$, $\Phi = 90° - \mu - \sin^{-1}\frac{M}{R}$ for $(\alpha+\gamma)$, $\Phi = \mu + \sin^{-1}\frac{M}{R} - 90°$	Same	Same	Same
Velocity of Follower	$K\omega$	$2K\omega\alpha$	$-2K\omega\alpha$	$3K\omega\alpha^2$
Accel. of Follower	∞ and 0	$2K\omega^2$	$-2K\omega^2$	$6K\omega^2\alpha$

* Sign of α for " Gravity " and " Cube " decelerations is negative

α = Any angular position of cam to give rise Y to follower
θ = Total angular movement of cam to raise follower distance L
r = Radius of base circle
R = Radius vector of center of follower
ϵ = Vectorial angle of radius $R = \alpha \pm \gamma$
μ = Angle between tangent to curve and R
Φ = Pressure angle
L = Rise of follower
M = Offset of follower
ω = Angular velocity of cam



Follower to Right or Left

Cube	Harmonic $H = L/2$	Cycloidal
*Deceleration		
$L - K\alpha^3$	$H - H \cos K\alpha$	$\frac{L}{2\pi}(K\alpha - \sin K\alpha)$
$-\frac{4L}{\theta^3}$	$\frac{180^\circ}{\theta}$	$\frac{360^\circ}{\theta}$
$D = T + L$		
$\sqrt{M^2 + D^2 - 2DK\alpha^3 + K^2\alpha^6}$	$\sqrt{r^2 + 2T(H - H\cos K\alpha) + (H - H\cos K\alpha)^2}$	$\sqrt{r^2 + 2T(K\alpha - \sin K\alpha)\frac{L}{2\pi} + (K\alpha - \sin K\alpha)^2\frac{L^2}{4\pi^2}}$
$\frac{3K^2\alpha^5 - 3DK\alpha^2}{R}$	$\frac{KH\sin K\alpha\,(T + H - H\cos K\alpha)}{R}$	$\frac{\frac{LK}{2\pi}(1 - \cos K\alpha)\left[T + \frac{L}{2\pi}(K\alpha - \sin K\alpha)\right]}{R}$
$1 \mp \frac{3MK\alpha^2}{R^2}$	$1 \pm \frac{MKH\sin K\alpha}{R^2}$	$1 \pm \frac{KLM(1 - \cos K\alpha)}{2\pi R^2}$
$\frac{(3K^2\alpha^5 - 3DK\alpha^2)R}{R^2 \mp 3MK\alpha^2}$	$\frac{KH\sin K\alpha\,(T + H - H\cos K\alpha)R}{R^2 \pm MKH\sin K\alpha}$	$\frac{LK(1 - \cos K\alpha)\left[T + \frac{L}{2\pi}(K\alpha - \sin K\alpha)\right]R}{2\pi R^2 \pm KLM(1 - \cos K\alpha)}$
$\frac{K\alpha[R^2(5K\alpha^3 - 2D) - 3K\alpha^3(K\alpha^3 - D)^2]}{R^3}$	$\frac{K^2H[M^2\sin^2 K\alpha + R^2\cos K\alpha\,(T + H - H\cos K\alpha)]}{R^3}$	$\frac{LK^2}{2\pi R^3}\left\{\frac{M^2(1 - \cos K\alpha)^2}{2\pi} + R^2\sin K\alpha\left[T + \frac{L}{2\pi}(K\alpha - \sin K\alpha)\right]\right\}$
$\mp\frac{6MK\alpha[R^2 - 3K\alpha^3(K\alpha^3 - D)]}{R^4}$	$\pm\frac{MK^2H[R^2\cos K\alpha - 2H\sin^2 K\alpha(T + H - H\cos K\alpha)]}{R^4}$	$\pm\frac{K^2LM}{2\pi^2R^4}\left\{\pi R^2\sin K\alpha - L(1 - \cos K\alpha)^2\left[T + \frac{L}{2\pi}(K\alpha - \sin K\alpha)\right]\right\}$
$\frac{R^2 \mp 3MK\alpha^2}{3K\alpha^2(K\alpha^3 - D)}$	$\frac{R^2 \pm MKH\sin K\alpha}{KH\sin K\alpha\,(T + H - H\cos K\alpha)}$	$\frac{2\pi R^2 \pm LKM(1 - \cos K\alpha)}{LK(1 - \cos K\alpha)\left[T + \frac{L}{2\pi}(K\alpha - \sin K\alpha)\right]}$
Same	Same	Same
$-3K\omega\alpha^2$	$KH\omega\sin K\alpha$	$\frac{L}{2\pi}K\omega(1 - \cos K\alpha)$
$-6K\omega^2\alpha$	$KH\omega^2\cos K\alpha$	$\frac{L}{2\pi}K^2\omega^2\sin K\alpha$

$$\text{Radius of curvature} = \frac{\left[R^2 + \left(\frac{dR}{d\epsilon}\right)^2\right]^{\frac{3}{2}}}{R^2 - R\frac{d^2R}{d\epsilon^2} + 2\left(\frac{dR}{d\epsilon}\right)^2}$$

$$\text{where } \frac{d^2R}{d\epsilon^2} = \frac{\frac{dR}{d\alpha} \times \frac{d^2\epsilon}{d\alpha^2} - \frac{d\epsilon}{d\alpha} \times \frac{d^2\epsilon}{d\alpha^2}}{\left(\frac{dR}{d\alpha}\right)^3}$$

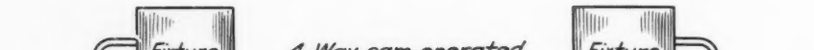
NOTE: $\epsilon = \alpha - \gamma$ for

1 Upstroke when offset to right and cam turns counterclockwise
2 Upstroke when offset to left and cam turns clockwise
3 Downstroke when offset to right and cam turns clockwise
4 Downstroke when offset to left and cam turns counterclockwise

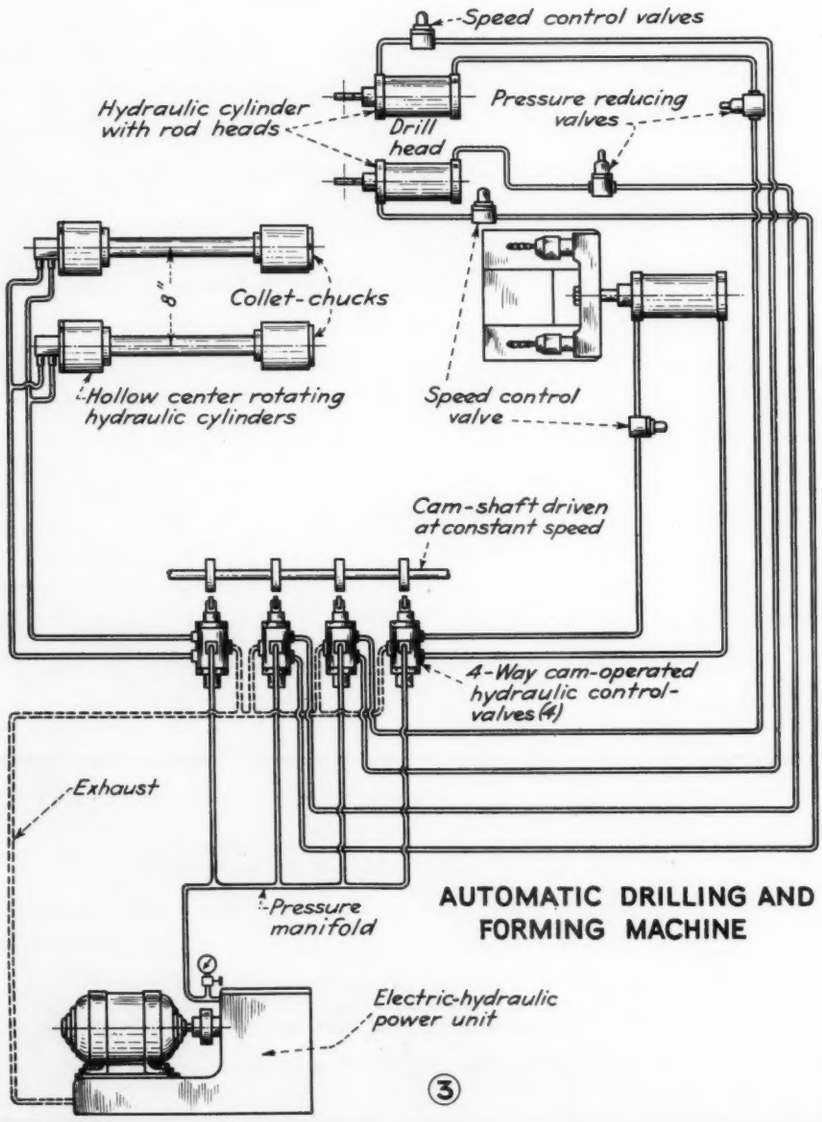
$\epsilon = \alpha + \gamma$ for

1 Upstroke when offset to right and cam turns clockwise
2 Upstroke when offset to left and cam turns counterclockwise
3 Downstroke when offset to right and cam turns counterclockwise
4 Downstroke when offset to left and cam turns clockwise

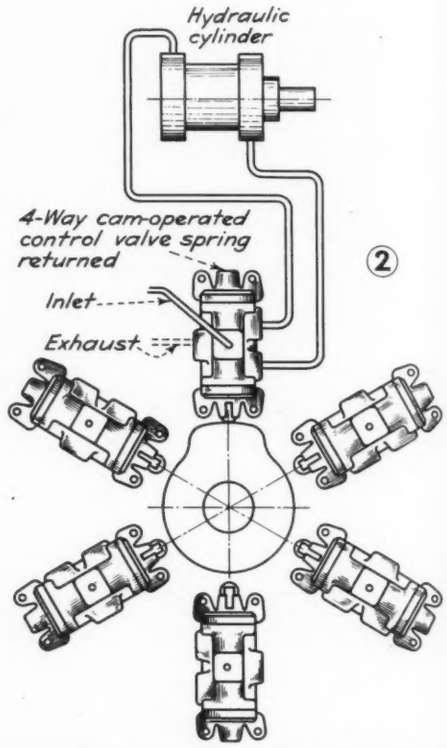
HYDRAULIC CIRCUITS



AUTOMATIC CONTROL OF FIXTURES ON MILLING MACHINE



AUTOMATIC DRILLING AND FORMING MACHINE



MULTIPLE VALVES CONTROLLED BY SINGLE ROTATING CAM

Fig. 1—Simple circuit automatically controlling clamping action of two fixtures on milling machine. Four-way cam-operated control valves attached to the reciprocating table clamp work when roller passes over stationary cams, then release pressure when roller drops free. Spring returns valve to normal position. Accumulator holds supply of oil under pressure, permitting instantaneous action and use of smaller pump.

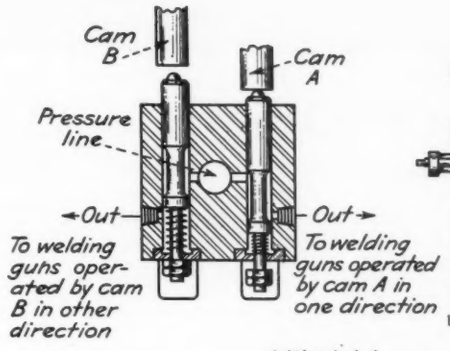
Fig. 2—Multiple valves operated by a single rotating cam give sequence control over cylinders for successive operations. The operation of each individual cylinder circuit can be varied by using reducing valves, by-pass valves or feed control valves.

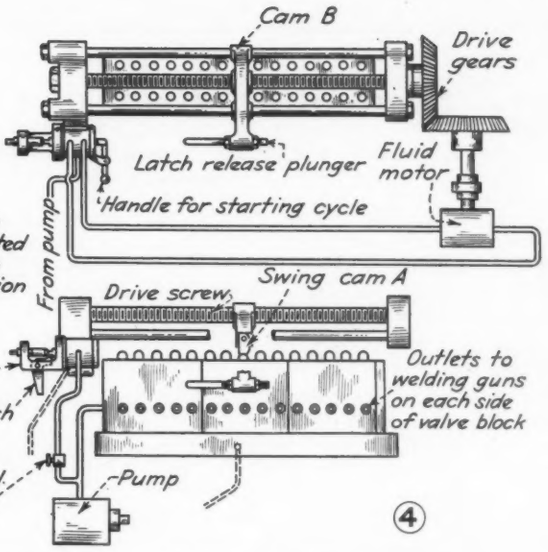
Fig. 3—Arrangement of cam shaft and four-way cam-operated spring return valves to control operation of an automatic drilling and forming machine. Cams are arranged on shaft to time operations, shaft being driven at constant speed by motorized speed reducer or equivalent. One valve controls two hollow-center rotating cylinders which operate chucks for holding the work, another controls cylinder which moves two drill heads, other two valves each control one cylinder which feeds forming tools into and out of the work.

Utilizing Cam-Operated Valves

J. C. COTNER
Logansport Machine, Incorporated

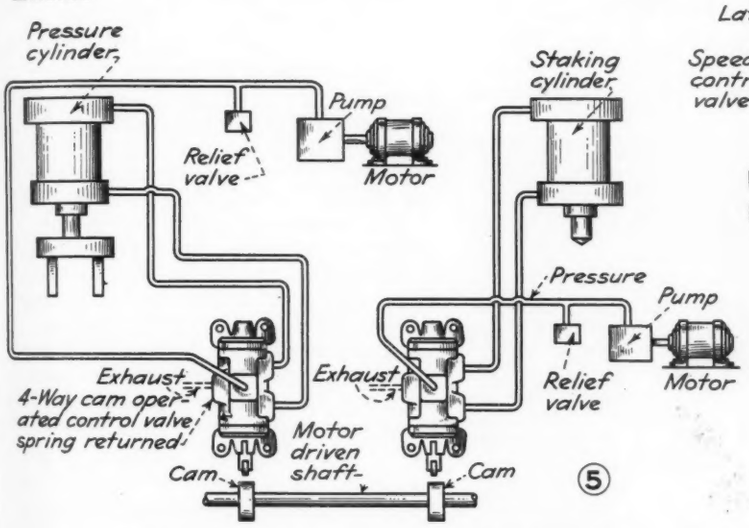
METHODS of obtaining and timing various machine motions by means of hydraulic circuits are shown in the accompanying diagrams. No particular emphasis has been placed on the pump and motor, attention has been confined to the possibilities that are attainable with valve arrangements with actuation by electrical and mechanical methods.


Cam B
Cam A
Pressure line
Out
Out
To welding guns operated by cam B in other direction
To welding guns operated by cam A in one direction



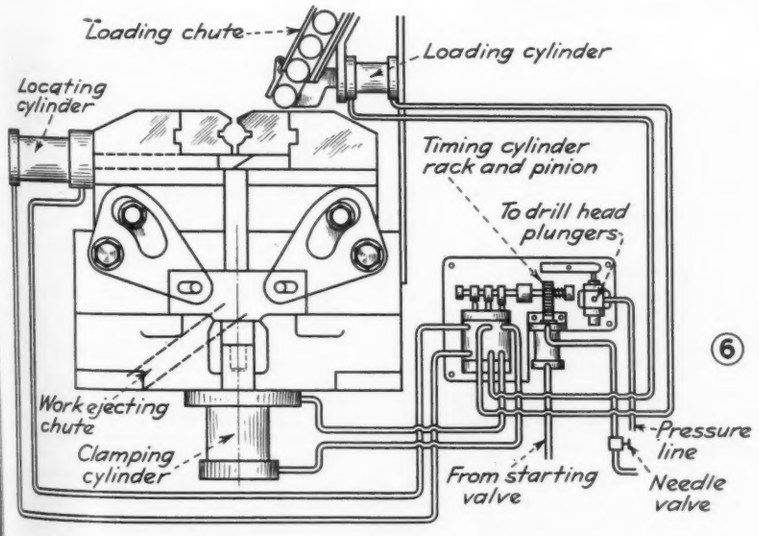
MULTIPLE VALVE CONTROLLING HYDRAULICALLY OPERATED GUNS ON WELDING MACHINE

Fig. 4—Arrangement of multiple three-way valves for controlling hydraulically operated guns on a Progressive type welding machine. Pump furnishes pressure through control valves to individual welding guns and through latch type valve to fluid motor driving screw through bevel gears. Drive screw head carries two cams which swing in opposite directions. When movement is in one direction, one cam swings free while the other pushes valve plungers down, moving piston in hydraulic welding guns for making weld. At the end of travel, the release plunger strikes a latch on the four-way valve, reversing the fluid motor for return stroke. At the end of return travel, the cycle is automatically stopped for reloading parts.



COMBINATION STAKING MACHINE AND HYDRAULIC PRESS

Fig. 5—Motor driven shaft has two cams for operating four-way, spring-returned valves which control combined staking machine and hydraulic press. A low holding pressure is needed on the press cylinder while high pressure and quick action is required for staking, hence two separate pumps are used with relief valves.



DOUBLE END HYDRAULIC MACHINE FOR REAMING PISTON PINS

Fig. 6—This automatic work-holding fixture is used with a double-end hydraulic machine for reaming piston pins at the rate of about 300 pins per hr. Shaft and cams which actuate three multiple four-way spring-returned valves are driven by rack and pinion. When starting valve is opened, pressure in small cylinder moves piston to which rack is attached. Needle valve on exhaust side of cylinder regulates speed of rack. Camshaft rotation causes valve to operate in proper sequence to operate cylinders for loading, locating, and clamping. When rack reaches end of stroke indicating piece is held in position, it strikes a bar connected to valve which starts operation of plungers. Starting valve is automatically reversed by drill heads.

Question and Comment

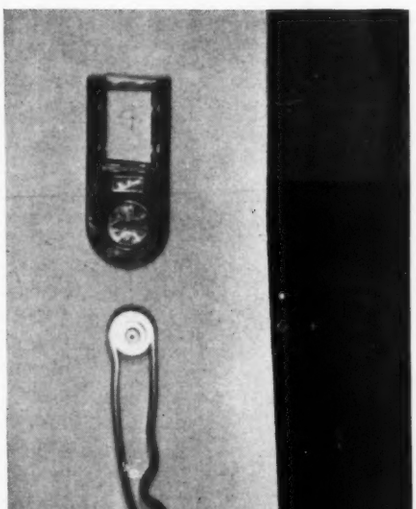
Some Observations on Chain Drive

E. S. AULT, *Professor of Machine Design*
Purdue University

THE ARTICLE on "Chain Drive Calculations," in the January issue of PRODUCT ENGINEERING is very provocative. It calls for a new analysis of chain forces from which we may be able to make some conclusions. After the discussion in the March issue, it is now apparent that Mr. Bremer and the Editor correctly agree with Messrs. Binder and Bolz that the freely driven chain will not leave the pulley because of centrifugal force; thus the caption of Fig. 5 in the January issue is accepted as improper.

It is stated that "the centrifugal tension is not developed until the chain has wrapped on the sprocket." This is not true because centrifugal force acts upon the chain whenever the chain is not traveling in a straight path. Messrs. Binder and Bolz demonstrated that the centrifugal force is independent of the radius of curvature of the path. Mr. Bremer admits the presence of centrifugal tension in the slack side, as it is obvious that the slack side hangs in a curve. This centrifugal force puts a tensile load on the chain between the sprockets, whether the chain is held to the sprockets by the teeth or not. Admittedly, the active load on the slack side of the chain is negligible, but what of the tight side? Might it not be possible that the tight side also moves with a definite radius of curvature? In that case, the tight side would be subject to centrifugal tension as well as working tension. We know that the pull on a chain to make it straight against the pull of gravity would have to be infinite.

Mr. Bremer can point to the successful transmission of power at high speed over a long period of time, but he partially explains that by the larger tooth numbers, careful installation, and excellent lubrication. The factor of safety of 20 used can conceal a large number of uncertainties. I believe that Mr. Bremer incorrectly infers from the paper of Messrs. Binder and Boltz that they disregard the effect of centrifugal tension on the tight strand. I understood that the same force was taken on the tight side in their two illustrations merely to give a common starting place for the analysis of forces around the sprocket with and without centrifugal force. They show that disregarding the effect of centrifugal force around the sprocket, the tension on the slack side is negligible. When considering the effect of centrifugal force, however, they get the tension on the slack side, T, equal to about 0.37 T_1. The torque transmitted is then $(T_1 - T_2)\ R$, where R is the pitch radius of the sprocket. Without centrifugal force the torque, $M_t = (T_1 - 0)R$, whereas with centrifugal force,



$M_t = (T_1 - T_2)R = (T_1 - 0.37\ T_1)R = 0.63\ T_1R$. Thus there is, for these figures, a decrease of one-third in torque. This demonstrates that the effect of centrifugal force does reduce the capacity.

The comments of the editor in the March issue concerning the effect of elongation do not seem valid to me. In the first place, if you do not admit of tension in the side plates *CB* (Binder and Bolz, Fig. 1) how can the load be transmitted through any but the first tooth of the driver and the last tooth of the driven sprocket? It is absolutely necessary to have tension in links *CB* and *BA* as well as a normal force from the sprocket tooth. A body acted upon by only two forces is not balanced unless the two forces are equal and directly opposed. The pressure angle between the tooth and roller is positive and the normal tooth force is not in line with the tensile force from link *BA*. The only other way in which a force can act upon the roller *B* is through link *BC*. An equilibrium polygon of these forces gives the values of these forces regardless of any elongation of the links. If chain pitches increase because of wear or elongation, the rollers ride out on the teeth at a greater radius, but the pressure angle between side plates and sprocket tooth is relatively unchanged.

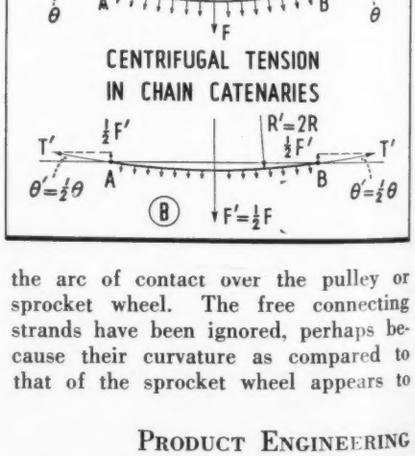
The pictures of the chain traveling at 5,000 ft. per min. on the pulley and on the sprocket shown by Mr. Bremer are very fascinating. I have never seen anything like the circle taken by the unrestrained chain. Were the directions of rotation of the two photographs as shown the same? They appear to be of opposite sense.

The illustration accompanying these comments was made from a photograph of a long chain rotating freely at a linear speed of about 450 ft. per min. This shows the peculiar action caused by the combined effects of inertia and friction forces that are not easy to evaluate. We have much to do yet to give an adequate quantitative explanation.

Centrifugal Tensions in Transmission Chains

To the Editor:

The question of tensions induced by the centrifugal forces in transmission chains does not seem to be thoroughly understood. In dealing with centrifugal forces, attention has been confined to



the arc of contact over the pulley or sprocket wheel. The free connecting strands have been ignored, perhaps because their curvature as compared to that of the sprocket wheel appears to

be small and therefore the centrifugal forces are small. It can be shown by a simple analysis that the tension induced in the free strands by the centrifugal forces developed in the free strands themselves is exactly as great as the tension induced by the centrifugal forces acting along the arc of contact.

In a chain transmission, the catenary formed by the strand of the driving side is flatter than that of the slack side because of the effective force transmitted. Because of the curvature of the free strands, they will be subjected to centrifugal forces developed in the strands themselves. The centrifugal forces, in tending to distend the strands, will be met by the reaction of the resulting tension, that is, the induced tension.

The total tension T at any point in the catenary is made up of two distinct tensions, one of which T_c is induced by the centrifugal forces, and the other T_g by gravity.

$$T = T_g + T_c$$

T_c equals wv^2/g and is constant.

The important facts are: The tension induced by the centrifugal forces developed in the free strands themselves is uniform throughout the strands. It is independent of the proportions of the catenary, and hence, independent of other forces acting on the strands. The presence of the tension induced by the centrifugal forces does not affect the proportions of the catenary, provided there is no additional stretch.

It can be readily shown that the tension produced by centrifugal force acting on the portion of the chain at the arc of contact is also wv^2/g, and that it is independent of the length of the arc of contact.

In summarizing, it can be said that the tension induced by the centrifugal forces is uniform throughout the whole chain, and because of its absolute independence, this induced tension is additive to other tensions already existing.

No account was made in the foregoing of the stiffness of the chain, the moment of inertia of its cross-section, nor of the finite length and individual moments of inertia of the links of the chain. These effects are ordinarily secondary.

The tension induced by the centrifugal forces being independent of the radius of curvature, while the centrifugal forces are themselves inversely proportional to that radius, it is difficult to visualize how the induced tension remains constant as the strands approach a straight line and the centrifugal forces tend to vanish. With the aid of the diagrams in the accompanying illustration the constancy of the induced tension can be explained.

Consider the portion AB, in Fig. A, of a strand subjected to its own centrifugal forces. Assume that the radius of curvature R is large and approximately constant throughout the portion AB. The tangents to the strands at the points A and B will then make equal small angles θ with a straight line through these points. If F is the resultant of all the elementary centrifugal forces, the components of the induced tensions T at the points A and B parallel to F must be of magnitude $\frac{1}{2}F$ in order to balance the resultant F. Since θ is small at A and B, $\frac{1}{2}F$ very nearly equals θT or

$$T = F/2\,\theta$$

If the radius of curvature is doubled, as shown in Fig. B but the speed of the strand remains the same, the new angles θ' of the tangents at A and B will be by geometry half as great as the angles θ; that is $\theta' = \frac{1}{2}\theta$. The centrifugal forces being inversely proportional to the radius of curvature, the new resultant F' will be one-half of F; that is, $F' = \frac{1}{2}F$. The components of the new tensions T' at A and B parallel to F' will be of magnitude $\frac{1}{2}F'$. Hence

$$\tfrac{1}{2}F' = \tfrac{1}{4}F = \theta'\,T' = \tfrac{1}{2}\,\theta\,T'$$

from which

$$T' = F/2\,\theta$$

That is $T' = T$. The induced tension has remained invariable. Carrying these steps further, it can be seen that as the radius of curvature is increased without limit, the centrifugal forces tend to zero, but the tension remains constant. The induced tension will exist, therefore, even when the free strands become straight.

The formula for safe loads in transmission chains approved by the American Standards Association is

$$T = \frac{2{,}600{,}000\,A}{600 + V} - \frac{WV^2}{115{,}900}$$

where A is the projected bearing pin area in sq.in., V is the speed in ft. per min. and W is the weight in lb. per linear ft. The second term on the right-hand side is the allowance for centrifugal tensions. With the speed expressed in ft. per sec., this term becomes wv^2/g.

It has been proposed recently to eliminate the centrifugal allowance in this formula, on the erroneous assumption that the induced tensions that might arise in the free strands are unimportant. Furthermore, it is argued that the centrifugal forces developed along the arc of contact are completely overcome by the reaction of the sprocket teeth before they have an opportunity to induce tensions. Thus, there will be no induced tensions in the chain to consider.

But whatever effects the reaction of the sprocket teeth might have along the arc of contact, the fact remains that the free strands develop a tension caused by the centrifugal forces in the strands themselves, independently of the forces acting along the arc of contact. This tension, furthermore, is precisely that given by the second term on the right-hand side of the American Standards Association formula, and this term must therefore be preserved.

Because, as far as the centrifugally induced tension is concerned, the chain is indifferent to its path, being, so to speak, in equilibrium with itself throughout, that tension will not increase the load on the sprocket teeth.

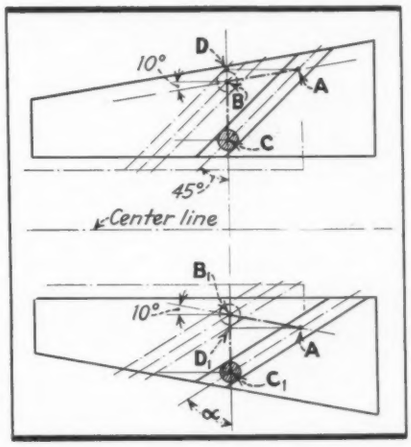
In considering fatigue, it must be remembered that the induced tension is a constant load, the fluctuating load being only that incident to the transmission of torque. Therefore, induced tension has little influence over fatigue.

J. J. Pesqueira
New York, N. Y.

Design Problem Involving Relative Motion

To the Editor:

In answer to C.W.H.'s problem in April Product Engineering, in order to move equally toward the die centerline, the two 10 deg. wedges must move equally along their hypotenuses, say,



A to B, in the figure, which must equal A_1B_1. This movement is obtained from a cross movement CB of the bar. Since the bar is rigid, CB must equal C_1B_1.

Therefore, lay out the triangle, ABC. Make BC equal to any assumed movement of the cross bar. Draw BA at the wedge angle (10 deg.) and draw CA at the groove angle (45 deg.) From the resulting triangle, measure or calculate BA, the distance that the wedge moves.

Then lay out the triangle $A_1B_1C_1$ making B_1A_1 equal to BA, but place the wedge angle (10 deg.) on the opposite side of the center line to correspond with the die wedges. Make B_1C_1 equal to the same assumed movement of the cross bar, that is, BC. Then connect C_1 and A_1 by a straight line. This triangle is not similar to triangle ABC. Angle C the desired angle of the groove in the lower wedge, may either be

measured or calculated from the known element of the triangle $A_1B_1C_1$. It will not be 45 deg.

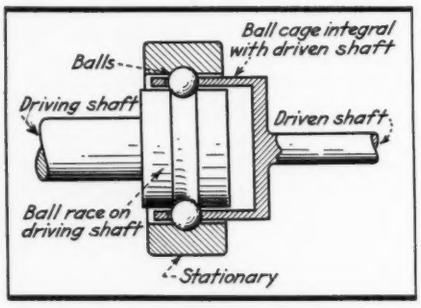
Erect DA through A and perpendicular to BC. Do the same through A_1. Then each wedge will approach the center line a distance equal to BD (equals D_1B_1) which can also be measured or calculated from the figure. The total, $2BD$, is the clamping movement. The velocity ratio is $2BD/BC$. The force ratio, neglecting friction is $BC/2BD$.

—Frederick Franz
New Haven, Conn.

Speed Reduction Unit?

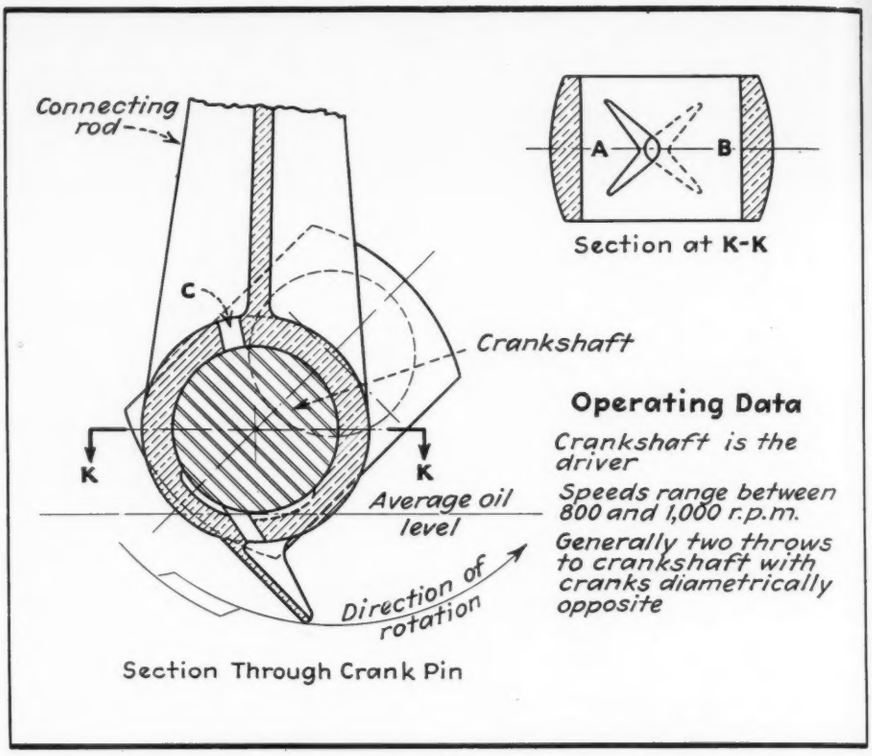
To the Editor:

Several years ago I saw an article on a speed reduction unit made from a ball bearing, in which the outer race was held stationary. The inner race was fastened to the driving shaft, and the retainer that positioned the balls was



fixed to the driven shaft. The accompanying sketch shows the construction of the unit. Can you tell me who built this and where I can get information concerning this unit?

M. J. N.
California



Let's Settle This Moot Question

To the Editor:

We manufacture a line of machines of various sizes with connecting rods and cranks operating in a bath of light oil, all within a closed crankcase.

For some time now there has been a highly controversial question in our plant as to the relative merits of various methods of grooving the connecting rods.

Some maintain that the grooving should be toward A (Section K-K on sketch) for a direct oil flow from the dipper, and others hold that the grooving should be towards B because the crankpin is wiping the surface in that direction. Another point argued is whether drilling a hole at C would be of any appreciable value in the solution of this controversial question.

—J. W. G.
Los Angeles, Cal.

Editors Note—Comments and opinions as to the relative merits of various methods of grooving the connecting rods are invited from our readers.

Can You Work This One?

H. E. SMITH

Solution to April problem—

Share of Expense

With the man who hired the team paying $4.00 to drive to the city 12 miles distant and return, the passenger who was picked up at a crossroads 6 miles distant for the trip to the city and return to the crossroads would share in the expenses, in one of two ways.

Figured on the basis of passenger-miles, the man who hired the team traveled a total distance of 24 miles and the passenger 12 miles. Total passenger miles, 36. Passenger's share of the expense would be 12/36 of $4.00 or $1.33. Now if we compute the passenger's proper share of the expense on the basis of wagon-miles we arrive at a different amount. The round trip of 24 miles cost the man who hired the team $4.00 or $1.00 for each six miles traveled. As the passenger rode 12 miles he should equally share the expense and pay one-half the cost for this distance or $1.00.

This month's problem—

Hat and River

Along a straight stretch of a river, two stakes showed above the surface of the water. They were a mile apart and directly up-and-down stream from one another. A man in a canoe between the two, paddling upstream, making headway against the current and so approaching the upstream stake. Just as he arrived at this stake, his hat blew off and went awash. The man realized his hat was very old, however well made, so he paddled on uninterruptedly upstream. At the end of ten minutes it occurred to him that the hat, however old, was very well made and could be rehabilitated. So he turned about and paddled downstream after the hat which he overtook at the downstream stake. Assuming that the man paddled at a uniform speed, the problem is to determine the speed of the current in the river?

News and Summaries

Department of Justice Indicts Bausch & Lomb Optical Company

Government charges contract with Carl Zeiss of Jena, Germany, has caused monopoly here on optical instruments for military purposes

RECENT NEWSPAPER ARTICLES reported the indictment of Bausch & Lomb Optical Co., Rochester, N. Y., on charges of monopolizing the domestic market for optical military instruments. In its indictment, the Department of Justice charged that "by reason of a contract with Carl Zeiss of Jena, Germany, Bausch & Lomb has been prevented from supplying foreign governments with optical gun-fire control instruments and further, that the contract has prevented Zeiss from supplying such instruments to the United States." As a result, it is alleged that Bausch & Lomb has been able to charge unreasonably high prices for instruments sold to the United States government.

In a statement issued by Bausch & Lomb Optical Co., concerning the indictments by the Department of Justice, it is pointed out that "its contractual relationship which began in 1921 called for royalty payments by Bausch & Lomb, in return for which they were entitled to receive from Zeiss, technical advice and assistance in connection with military instrument development work." Bausch & Lomb also acquired an exclusive license to manufacture under all Zeiss military instrument patents in the United States."

"The purpose and effect of this contract," Bausch & Lomb states, "is to place at the disposal of the United States government such Zeiss inventions as were useful in the development of the government's optical military instrument program. The indictment charges that this has been a means of monopolizing the domestic market.

Bausch & Lomb further states that "it has supplied military instruments to the United States government at prices based solely upon its own costs which are subject to no control under the Zeiss contract." Furthermore the company claims that, "during the past ten years, the average net profit on military business has been less than 5 per cent. "Outbreak of the war in Europe last year has rendered further performance by Zeiss impossible. The contract expires in 1941."

Prices at which Bausch & Lomb has supplied military instruments to the government are claimed to "have been based solely upon its own costs and subject to no control under the Zeiss contract."

"We have made no secret of our Zeiss arrangements," stated Bausch & Lomb. "The Navy Department was advised of the existence of the contract within a month after its execution. A copy of the contract was handed to the Department of Justice and became a public record when filed with the Securities and Exchange Commission in 1937."

"We have been informed by officials of the Navy Department," Bausch & Lomb report, "that the technical information and assistance which the company has received from Zeiss over the years has been of great benefit to the Navy in the development of optical gun-fire control apparatus."

Photostat Service New Library Aid

PHOTOSTATS and microfilm copies of material contained in the 160,000 volumes and periodicals on the shelves of the Engineering Societies Library, New York City, can now be obtained at cost, it was recently announced by Harrison W. Craver, director of the library.

This service considerably increases the availability of all the library material. For those wishing to photograph their own material, a photographic copying stand has been installed.

Graph Standards Ready For Approval

A NEW PROPOSED STANDARD for engineering and scientific graphs is now being circulated for suggested changes before being submitted to the technical committee of the American Standards Association.

The standard covers design and layout; construction of original graphs to be used for reproduction; and handling of finished illustrations. Many illustrations are contained in the proposed standards presentation.

Work on uniform standards has been in progress since 1914. Originally undertaken by the American Society of Mechanical Engineers in 1925, the work was taken over by the A.S.A.

Copies of the proposed standard may be obtained from, and suggestions for changes sent to, the American Society of Mechanical Engineers, 29 West 39th St., New York City.

Westinghouse Annual Forum To Be May 6-8

A DISCUSSION of new electrical features and applications available to solve problems of the machine tool builder will be a feature of the 1940 Machine Tool Electrification Forum to be held May 6–8 at the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

An outline of electric drive and control for special purpose grinding machinery will be given by Roger S. Pyne, chief engineer of Van Norman Machine Tool Co. Problems of control, wiring and installation will be discussed by D. K. Frost, electrical engineer, Mattison Machine Works.

Synchro-tie apparatus, the "electrical lineshaft" for keeping machine functions in step with each other, will be described in theory and actual applicaton. D. L. Hadley, Westinghouse consulting engineer, will demonstrate the principals of industrial design, applied to utilitarian motors and control apparatus. Many other subjects will be discussed.

Actual Metal Strength Less Than Theoretical

WHILE SOME properties of metals can be calculated accurately on paper, the problem of tensile strength continues to baffle the scientist, Dr. Saul Dushman of the General Electric Research Laboratory said at a recent meeting of the Detroit Chapter of the American Society for Metals. The ultimate tensile strengths of metals, he explained, are only one-tenth to one-hundredth of what theoretical calculations of the physicist say that they should be.

"On the basis of the electronic theory of atomic structure and quantum mechanics," Dr. Dushman said, "it is possible to account for the typical metallic properties such as electrical and thermal

conductivity, the occurrence of magnetism for some of the metals, and observations on the relation between composition and phase pattern for a number of alloys.

"In the case of the alkali metals and copper it has been found possible to calculate heat of evaporation and compressibility from the known electron configurations of the atoms.

"However, such 'structure sensitive' properties as tensile strength, rate of creep under stress, especially at higher temperatures, phenomena of recrystallization and age-hardening cannot be interpreted on any purely atomic basis.

"It seems to be generally accepted that fine cracks or similar defects in crystalline structure account for the discrepancy between observed and calculated tensile strengths. For instance, the ultimate tensile strength increases with decrease in size of wire, with decrease in grain size, and with increase in cold working.

"The observations in which the metallurgist is interested are so varied and so extremely complex that progress towards a satisfactory explanation must necessarily be slow. We are dealing in nearly all cases with phenomena in which the energy changes involved are relatively small, and to calculate them involves from the point of view of atomic structure, a consideration of second and third-order perturbation effects. What we need at present is not so much a study of engineering materials as of pure metals and simple binary alloys."

Dr. Dushman listed cohesion and plastic deformation as the most important metallurgical problems. He said that tensile strengths of metals are not only considerably less than those calculated on a theoretical basis but that tensile strength and other cohesive properties may be varied over large ranges by varying the composition, by heat-treatment, and by mechanical working.

Straightening rotor by heat treatment. A machined shaft or rotor is suspended in a standard lathe bed in a specially-built oven in which controlled heat is applied through strip heaters. Rotor is turned at 2 r.p.m. and temperature readings obtained with thermocouples. Sliding rods passed through the wall and riding against rotor indicate shaft deflection as temperature is increased. At a certain critical temperature, straightness is restored and is not affected by further temperature changes. Development won S. Homer Weaver, General Electric Company, the Charles A. Coffin award.

Metallic Vapor Lamps Newest Development

MOST INTERESTING characteristic of a new tellurium-vapor arc lamp, recently constructed by Dr. J. W. Marden, Dr. N. C. Beese and George Meister at Westinghouse Lamp Division research laboratories, Bloomfield, N. J., is its ability to produce a continuous visible spectrum of light almost identical with that of direct sunlight. This desirable "daylight" output is achieved at low operating temperature, low internal pressure, and low power input to the lamp, which is the converse of incandescent lamp behavior.

Two other new lamps, employing the same fundamental principles as the tellurium lamp but having radically different characteristics, use zinc and cadmium vapors. Like mercury-vapor lamps, these light sources have most of their visible output concentrated into a few spectral lines. Although all three lamps are now little more than laboratory curiosities, they do represent scientific development.

Do You Know That—

A METHOD HAS BEEN FOUND of detecting radio waves emitted by atoms and molecules. These waves are in the short-wave band, but you can't get them with your set. (9)

GRINDING WHEEL DRUMS are now being made with an inflated rubber inner tube to hold the abrasive band in place. Finer finishes, with less danger of tearing the work or putting excessive wear on the abrasive bands are promised. (10)

NEW STYLE GAS TANKS are flexible bags of airplane cloth impregnated with neoprene and are contained in light-weight frames which fit into the wings, pontoons or other parts of the plane. Many advantages are claimed such as easy repair by simple patches and cement; easy removal and replacement; greater fuel capacity and elimination of corrosion. (11)

Meetings

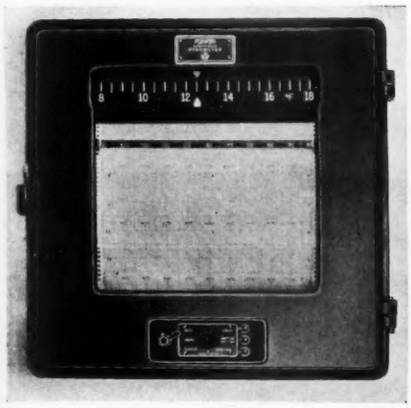
AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Spring Meeting Hotel Bancroft, Worcester, Mass. May 1–3. C. E. Davies, secretary, 29 W. 39th St., New York, N. Y.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Semi-annual meeting, Hotel Pfister, Milwaukee, Wis., June 17–20. C. E. Davies, secretary, 29 W. 39th St., New York, N. Y.

New Materials and Parts

Potentiometer Recording Controller

New series of potentiometer recording controllers, incorporate an improved detecting mechanism, a new integral recording and control mechanism, and a new control system to provide maximum flexibility of use. Open-and-shut action



or throttling action, with or without automatic reset, is available in air-operated models.

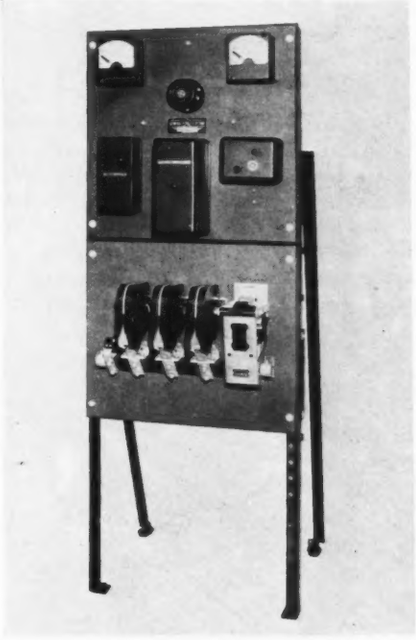
To obtain a more sensitive detecting mechanism than that required for recording, a single, calibrated detecting cam is used which will sense deflections of the galvanometer pointer of less than 0.0001 in. without lost motion. By positioning a friction roller, the cam positively determines the movement of the integral slide-wire contact recording and control actuating carriage. Coordination of measuring, recording and controlling operations is achieved by an integral recording and control mechanism. The slide-wire contact, recording pen and cam follower actuating the control cam are assembled as a unit on the same rigid carriage. Guaranteed accuracy is ¼ of 1 per cent of scale range. The Foxboro Co., Foxboro, Mass.

Flame-Hardening Process

Known as the Vertical Combination Method, has been developed with which it is possible to raise the hardness of 65-70 carbon steel cylindrical objects to approximately 90 or better on the Type "C" Scleroscope. The process has also been tested in hardening a special dry sand alloy cast iron with which an average hardness of 80 on the Type "C" Scleroscope has been obtained. It is claimed that rolls which have been flame-hardened by this method show no measurable distortion. Overlap from the flame is eliminated because the process is continuous, using a large number of flame tips which are followed immediately by a water spray quench. The process is suitable for rubber engraving rolls, embossing rolls, calender rolls under certain conditions, and types of mandrels where excessive pressure or wear must be taken into consideration. Farrel-Birmingham Co., Inc., Ansonia, Conn.

Synchronous Motor Control

Synchronous motor control featuring the slip-cycle impedance SCI relay. Device allows accurate control of synchronizing speed, so that field cannot be applied until the motor has reached a speed at which it can synchronize its



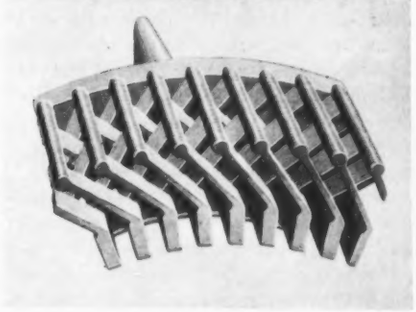
load. Current and torque fluctuations are avoided. When motor reaches correct speed, control selects an instant of favorable angular-relation of stator and rotor poles at which to apply field to take advantage of the inherent synchronizing ability of the motor. The SCI relay also prevents pulsations in case of motor pull-out by disconnecting the power or field if automatic resynchronization is desired. Protection of the squirrel-cage winding during starting and the stator winding during running is provided by separate relays. Available for control of all ratings of synchronous motors in magnetic or semi-magnetic forms for full voltage, reduced-voltage, or part-winding starting. General Electric Co., Schenectady, N. Y.

Clear Print Inks

Fast drying inks which are claimed to be non-fading and non-reflecting for use in marking or stamping lacquered, varnished, and glazed papers and metals. This ink will also stamp on film, foil and other cellulose acetate materials with non-absorbent surfaces. Silk fabrics for typewriter ribbons are also available which have been impregnated with the ink for typing on film, foil, tracing cloth and paper. The pads to ink the rubber stamps are chemically treated Balsa wood blocks. The surface of the pad is kept inked to the proper degree by capillary action, thus insuring even inking of the base of the type. Phillips Process Co., Rochester, N. Y.

"Valv-Amp" Rotor

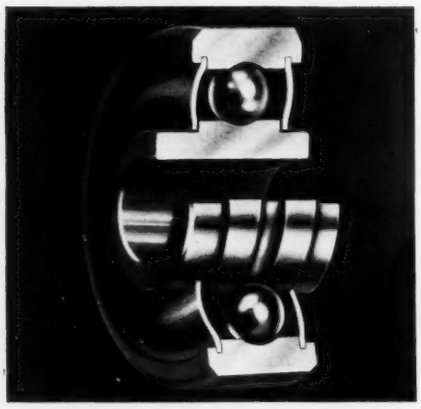
New type rotor construction makes possible the use of cast-aluminum rotors in the larger sizes of double-squirrel-cage motors for high-starting-torque, low starting-current service. "Valv-amp" rotor has a unique shape of rotor slot and utilizes a special method of assemblying rotor punchings to control the flow of starting current. As a result, without the use of a switch or other moving parts, current is permitted to flow in the outer squirrel-cage when the motor



is started and thus produce high-starting torque. When the motor comes up to speed, current is allowed to flow through the entire rotor "winding", resulting in good running characteristics. General Electric Co., Schenectady, N. Y.

Aircraft Control Bearings

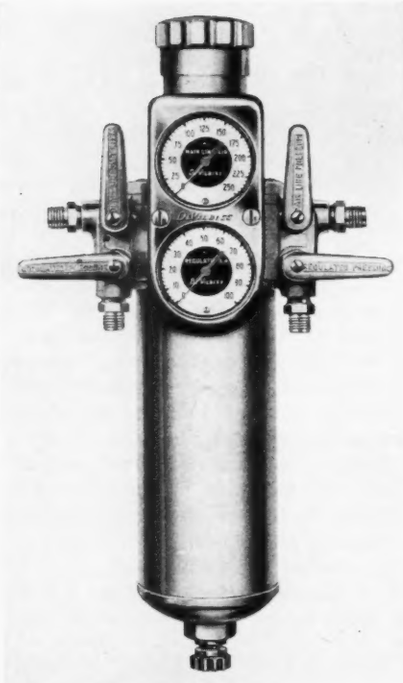
Ball and roller bearings for aircraft having a full complement of balls or rollers enclosed with corrosion-resisting metal plates, or felt seals, to conform to AN specifications. These bearings, or



their assemblies, are used as hinge bearings on control surfaces, leverage mechanisms in the control surface or engine control systems and in control pulleys in order to provide a sensitive and positive control system with a minimum of friction as required by the high speeds, heavy wing loadings and increased maneuverability of modern military and commercial airplanes. SKF Industries, Inc., Philadelphia, Pa.

Air Transformer For Spraying Equipment

Recently announced a new air transformer, type HLC, has increased capacity, improved filtering facilities and more sensitive regulation and control of pressure. The transformer handles in excess of 50 cu.ft. of air per min., with a minimum of pressure drop and will pass ample air for two production spray guns in continuous and simultaneous operation or for three spray guns in ordinary intermittent operation. Constructional features include a synthetic rubber regulator diaphragm, improved operating mechanism and a conveniently located regulator knob. A large condensing chamber permits air expansion and condensation of moisture. Further effectiveness in air cleansing is accomplished by an improved baffle arrange-



ment. A new metal filter, wholly mechanical, eliminates the old-fashioned cotton waste pack and the necessity of its repeated removal and replacement. Inclosed pressure gages and a die-cast body complete the transformer. The cylinder is chromium plated and highly polished. De Vilbiss Co., Toledo, Ohio.

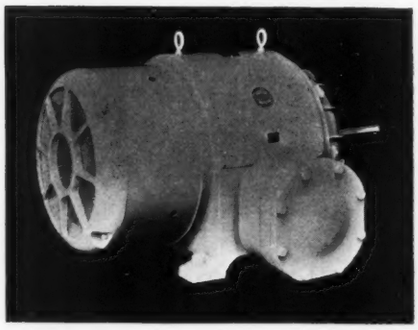
Toggle Switch

Switch is provided on sides with strong springs so that it can be snapped into or easily removed from a control panel. A rectangular hole in equipment is all that is needed for assembly. The switch has positive action silver contacts to make and break current. The switch is a single pole on-and-off design, in-

tended to control warming ovens and electric ranges, to control the range light, and for radio control panels. The switch may be furnished in either black or white plastic shell and handles. The Hart Mfg. Co., Hartford, Conn.

Large Size Explosion-Proof Motors

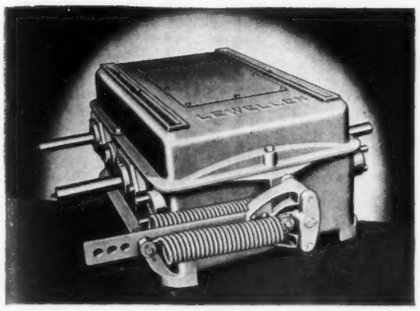
In Class I Group explosion-proof motors, approved by the National Board of Fire Underwriters, ratings have been increased from 25 to 75 hp., while in Class II Group G ratings have been increased from 7½ to 75 hp. The larger motors are of shell type frame construction and have a specially designed fan quiet at high speeds. Motors are fitted with a new larger terminal box. The fan-end inner-end bell and the outer fan cover brackets are held in place with a simplified-type combination screw which eliminates one set of holding



screws and supplies rigid mounting for the fan cover and bracket as well as facilitating the assembly or disassembly of the motor. U. S. Electrical Motors, Inc., Department 112, 80—34th St., Brooklyn, N. Y.

Variable-Speed Transmission With Safety Control

Special transmission developed to regulate stoker speeds for feeding fuel at rates that maintain automatically boiler pressure setting. A slight deviation of boiler pressure will result in a movement of the pressure control connected to the safety lever on the transmission. While the lever follows any rapid motion of the controlling device, speeds are adjusted only at a safe controlling rate of acceleration, as speed is changed gradually by spring action. Control lever does not operate the transmission directly. The boiler control may move the lever over as much as 90 deg., placing a tension on the springs. Springs in turn move the shifting mechanism in the transmission to increase or decrease the



speed of the variable shaft. Lewellen Manufacturing Company, 1030 E. 10th St., Columbus, Indiana.

Pneumatic Industrial Caster Tire

Designed for use on a swivel caster unit on industrial trucks, this new pneumatic tire comes in 10-in. and 12-in. six ply and has a smooth, narrow tread. Previous efforts to develop a pneumatic tire for a caster unit had failed because of the wiping action caused by the comparatively large area of rubber in contact with the floor surface, this condition

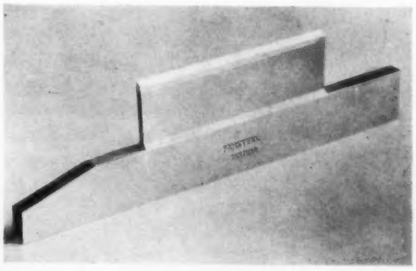
preventing the caster wheels from turning easily and smoothly. General Tire & Rubber Company, Akron, Ohio.

Fractional Horsepower Motor

Ball bearing and self-aligning sleeve bearing shaded-pole motors, with high locked rotor and accelerating torque, differ from most fractional hp. motors in that the mechanical system does not depend on the stator for alignment. This is accomplished by means of die cast end frames with a spacer shell held in compression by means of through bolts. This design permits a recess in the end frame for the spacer shell and a second recess which positions and locates the stator. The ball bearing motors will operate in any position and will withstand substantial end thrust. Power output ranges from 3 to 15 watts. The motors are of four-pole design with top speed of 1,600 r.p.m. Russell Electric Co., 340 W. Huron St., Chicago, Ill.

Grinder Blades Faced With Wear Resisting Alloy

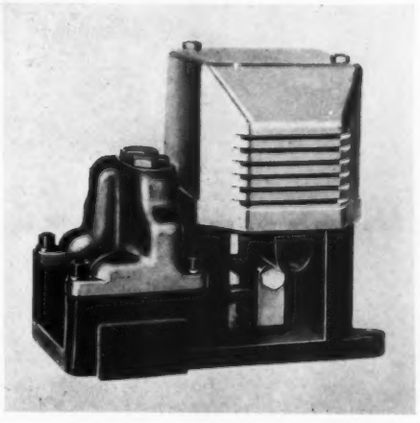
Centerless grinder rests for any type of machine or grinding operation faced with a tough, slow wearing alloy. The hard facing Tantung, is composed of hard particles of tantalum and tungsten carbide uniformly distributed and embedded in a strong, tough matrix. The Tantung facing, made in bar form, is affixed to the steel supports by a special



brazing process. Complete blades are manufactured to specification, Tantung facing can also be applied to existing or worn-out blades. Fansteel Metallurgical Corp., North Chicago, Ill.

High Speed Air Valve For Welding Guns

Solenoid-operated air valve, built for high-speed operation of welding guns,



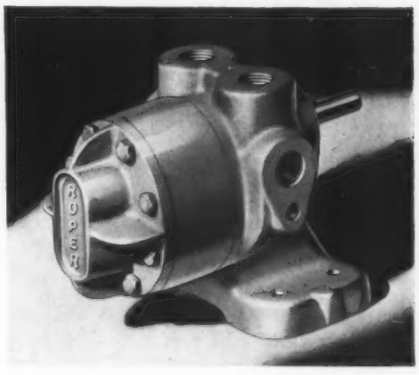
has been announced. Valve is now regularly delivering 400 welds a minute on production jobs. Ross Operating Valve Co., Detroit, Mich.

Anti Acid Enamels

Unaffected by acids, fumes, alkalis, gases and other destructive chemicals. "Devilac" enamel, type 9N9, is air-drying, applicable by brush or spray gun and will not be affected by commercial concentrated Sulphuric, Nitric, Hydrochloric, Hydrofluoric acids, alkalis and gases. Other types are available for particular requirements. Rogear Co., 11 Water St., New York City.

Rotary Pumps

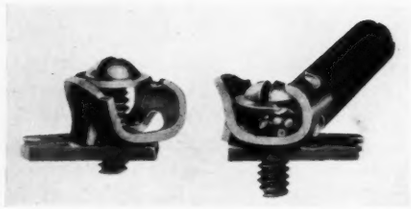
New line of rotary pumps contain over 7,000 different units including pumps of 1, 3, 5, 10, 15, 20, 35, 50, 75, 100, 150, 200, 300, 500, 750 and 1000 g.p.m. capacities at speeds up to 1,800 r.p.m. and against pressures up to 1,000 lb. per sq. in. Twenty-one different drives and mountings are available ranging from ordinary foot, hub and flange mounting heads to complete bedplate units for direct motor drive; gear reduction; flat or V-belt drive. Other features include choice of spiral, spur or herringbone gears; conventional packing box,



spring-loaded packing box or mechanical seal; sleeve or roller bearings; built-in or external relief valve; and eight different piping arrangements. Geo. D. Roper Corp., Rockford, Ill.

Solderless Connector

A new solderless connector will take from No. 14 to No. 4 wire. It is free to rotate around the screw, thus allowing wire to be inserted from almost any angle, important where large wires are used in a limited space. The unusual range in wire size permits the use of large wires for service drops to small 30 or 60 ampere switches. Connector is self-centering, there is no need to wind the wire around the stud or to separate stranded conductors. As the screw is tightened, the lug is forced to one side and the wire is gripped tightly. When the tightening is completed, the screw exerts pressure against the wire on one



side and the lug on the other side, thus bending of the screw is prevented. Square D Co., Detroit, Mich.

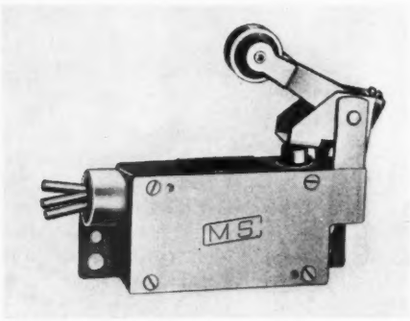
Handy Three-Piece Ink Stand

For filling ruling pens. Stand consists of three parts: a stand which holds the regulation ¾ oz. bottle of ink; a dipper arm which closes the bottle when not

in use; and a finger-touch lever which raises a filling loop on the end of the arm. A rubber stopper on the dipper arm seals the bottle against evaporation. Filling loop may be lowered or raised according to the level of ink in the bottle or to the amount of deposit desired. Stand is non-tippable and may be screwed to the drawing board. A patented device locks bottle tightly when not in use. Eugene Dietzgen Company, Chicago, Illinois.

Micro Switch with Roller Actuator

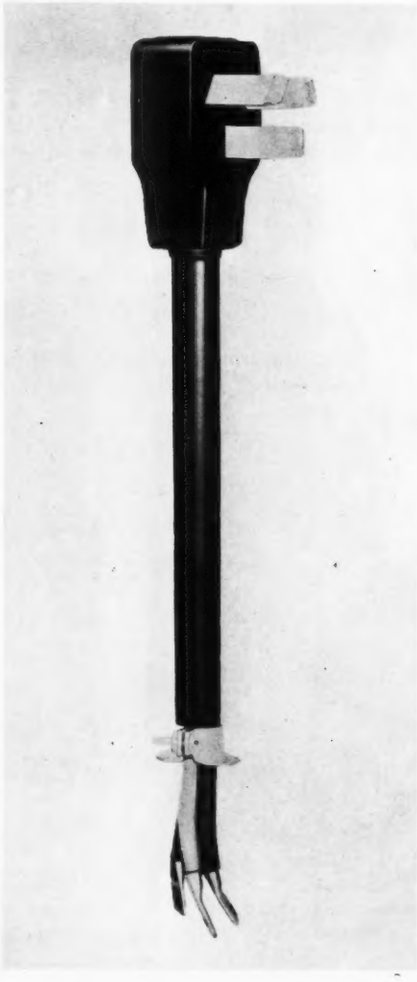
Model LK-2, a new precision limit switch for actuation by rotating or sliding cams, has a roller actuator adjustable through an arc of 225 deg. Switching element contained in the steel housing is a single-pole micro-switch with normally open, normally closed, double-throw contact arrangements. Movement differential at the roller is 0.002 in., pretravel is one deg., overtravel is 20 deg., and operating pressure is less than 1.8 lb. Interchangeability is possible because operating point is held within plus or minus 0.002 in. with relation to mounting dowels. Switch is resistant to oil



and water, has a life of over a million operations, and is underwriters' listed, H.E.P.C. approved. Rated at ½ hp. up to 460 volts a.c. Micro Switch Corp., Freeport, Ill.

Three-Wire Unicord

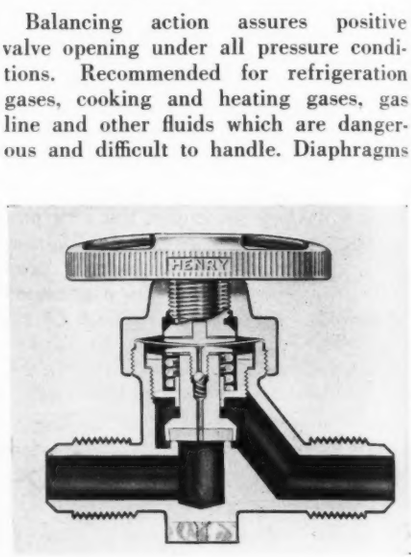
Plug is rubber molded directly to three-wire rubber range cable. Attachment plug has prongs which form an



inverted pyramid. A new cord makes it possible to connect electric ranges at terminal blocks near the floor line to outlets with a single smooth bend in the conductors. This new G-E range Unicord line is available with two No. 8 and one No. 8 conductors, or with two No. 6 and one No. 8 conductors. General Electric Co., Bridgeport, Conn.

Packless Diaphragm Valve

Balancing action assures positive valve opening under all pressure conditions. Recommended for refrigeration gases, cooking and heating gases, gas line and other fluids which are dangerous and difficult to handle. Diaphragms



furnish a hermetic seal whether the valve is open or closed. An equalizing or balancing action allows the use of a lighter spring to lift the stem from the valve seat when the handwheel is turned to the open position. Handwheels are oval in shape, affording a natural gripping surface. Made in all standard types, 2-way, 3-way and angle. Size ranges for flare fittings, ¼ to ⅝-in.; solder connections, ¼ O.D. to 1⅛ O.D.; and male pipe thread ¼ to 1-in. Henry Valve Co., 1001–19 N. Spaulding Ave., Chicago.

Capacitor Motor

Designated as a capacitor motor, it can be supplied with three different windings-synchronous capacitor, non-synchronous capacitor, and dynamic breaking capacity. Principal use is on devices designed for continuous operation. Standard ratings at 60 cycles are, respectively, 1/1,500 hp. at 1,800 r.p.m.; 1/1,000 hp. at 1,700 r.p.m.; and 1/1,500 hp. at 1,200 r.p.m. Motor input is 8 watts or less. Standard windings are for 110 volts, a.c., motors wound for lower voltages can be built on order. This new motor (type K) is small and weighs less than 1½ lb. Bodine Electric Co., 2260 W. Ohio St., Chicago.

Books and Bulletins

Design This Day

WALTER DORWIN TEAGUE—*284 pages, 6¾x9¼ in., plus 128 pages of illustrations. Clothboard covers. Published by Harcourt, Brace and Company, 383 Madison Ave., New York, N. Y. Price $6.*

In the first two chapters of the book the author presents a highly interesting picture of man's progress from savagery to the present and discusses the forces now at work to bring about a new world, in spite of present conditions. Without wasting words, Mr. Teague convincingly shows that neither armed might nor so-called social planning can solve the problems of today but that humanity must look more and more to science and technology for the means to enable man to adjust himself to the upheavals created by the machine age. The alliance between science and industry is the most potent force yet seen in the continued advancement of human welfare.

The last fifteen chapters deal mainly with the fundamental factors that affect beauty. Although several of these chapters contain definite mathematical rules of design, the purpose of the author is evidently to present a philosophy of design rather than rules. In this he succeeded admirably. His numerous brief historical references, his short discussions of the present state of design, and his comments on present art and living make this book highly interesting, instructive and well worth reading. It is an excellent companion to Harold Van Doren's book, "Industrial Design," which was reviewed in our April number.

The Pageant of Electricity

ALFRED P. MORGAN—*363 pages, illustrated, 5½ x 8½ in. Blue clothboard covers. Published by D. Appleton-Century Co., Inc., 35 W. 32nd St., New York, N. Y. Price $3.50.*

In this book is presented in interesting narrative form the development of electrical science from its beginnings with the Greek philosopher Thales in 600 B. C. down to the present day. Roger Bacon, Galvani, Volta, Oersted, Faraday, Morse, Edison, Bell, Pupin and Marconi are among the electrical pioneers whose life and works are covered in excellent literary style. The book also includes the story of the development of electricity into its dominating industrial applications; telegraph, telephone, power generation, radio, transportation and electrochemistry.

No attempt is made to go into the intricacies of electrical phenomena; technical explanations are given in connection with illustrations and are not a part of the narrative. A chronological table and comprehensive index complete this valuable historical reference text.

Chemicals of Commerce

FOSTER D. SNELL and CORNELIA T. SNELL—*542 pages, 5½x8½ in. Black fabricoid covers. Published by D. Van Nostrand Company, Inc., 250 Fourth Ave., New York, N. Y. Price $5.*

This volume has been prepared to fill the need for a source of information on the composition of commercial products. It is not a chemical dictionary. The term chemical is used with a very broad meaning and is intended to cover basic materials; in many instances these are more or less pure chemical compounds, in others they are mixtures containing several ingredients.

The book gives in brief concise form the salient facts about any class of materials. Classification is by type of compound, so that closely related substances occur in the same chapter. Each chapter starts with a discussion which gives the reader the general background and chemical nature of that particular group of substances.

Cast Metals Handbook

1940 EDITION—*532 pages, 6x9 in. Brown clothboard covers. Published by American Foundrymen's Association, 222 W. Adams St., Chicago. Price $5.*

This 1940 edition records much of the progress made in the field of design, manufacture and application of cast metals and castings since the publication of the 1935 edition. The data and information contained in the first edition has been thoroughly revised and expanded to bring the Handbook up to date.

Under sections devoted to cast steel, malleable iron, non-ferrous alloys and cast iron are presented data and information covering design, physical testing, metallurgy, manufacture, specifications and applications of metals in the respective groups. Many illustrations and tables are used throughout the book to supplement the text.

Engineers who design or specify metal castings in their products will find this book a valuable asset. It is an extremely practical book, written by a group of men who are actively associated with the foundry and its technique.

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Retainer, Bearing, Lock and Snap Rings

Engineering Data Book, No. 40—40 pages, 8½x11 in. Paper covers with coiled wire hinge. Published by Eaton Manufacturing Company, Reliance Spring Washer Division, Massilon, Ohio.

Contains technical detailed information of value and interest to engineering designers who specify steel rings as parts in mechanical products or who are concerned with the application and performance of steel rings of various types.

The engineering data presented deals with steel wire sections, design and shape of end cuts, permanent set, elastic limit, Rockwell hardness, frictional thrust resistance, uniformity of heat-treatment, groove fit and installation. The section on snap ring stresses is especially valuable. Tabular matter deals with material specifications, ring types, installation and dimensional tolerances. The book is amply illustrated with halftones and numerous line cuts to supplement text.

The Fabrication of U.S.S. Stainless Steels

Book, 92 pages, 6x9 in., stiff covers. Published by Carnegie-Illinois Corporation, Pittsburgh, Pa. Price $1.

Discusses the technical and practical aspects of stainless steel fabrication. Part I is devoted to welding, riveting, soldering and joint design. Part II deals with machining, cutting, forming, annealing and pickling operations with recommendations as to equipment and temperatures. Part III discusses surface finishing and protection, standard mill finishes and the operations involved in securing the desired finish. Corrosion data, physical and mechanical properties are included with many valuable and practical notations as to abrasion resistance, cold forming and welding.

Arc-Welding Award Program

Brochure, 48 pages, 8½x11 in. Published by the James F. Lincoln Arc Welding Foundation., Cleveland, Ohio.

Titled, "The $200,000 Industrial Progress Award Program", the brochure announces the purpose of the Progress Program, indicates the wide scope of the program and lists the 12 classifications and 46 divisions which cover every branch of the industrial field. This award program sponsored by the James F. Lincoln Arc Welding Foundation offers 458 awards totaling $200,000. About half the publication is devoted to listings and illustrations of typical subjects for study in the divisions of the program.

Manufacturers' Publications

Materials

ALLOY STEEL—Jessop Steel Co., Washington, Pa. Booklet, 8 pages, 5x7½ in. Description, application, working data and analysis of "Truform," an oil hardening, nonshrinkable alloy tool steel.

SOLDERING FLUXES—American Chemical Paint Co., Ambler, Pa. Bulletin No. 5, four pages 4x8½ in. This folder tells in brief but complete fashion the properties and applications of four soldering fluxes. On the last page are short descriptions of ten representative products of the company.

STEEL—Republic Steel Corp., Cleveland, Ohio. Forty pages 8½x11 in. Gives complete information on "Republic Double Strength Steel", a high tensile, low alloy product. Many interesting pictures, combined with complete engineering data and performance records make the book of worthwhile interest to designers, engineers and fabricators interested in this type steel.

TENITE—Tennessee Eastman Products, 10 E. 40th St., New York, N. Y. Catalogs for the engineer. Three new books form a good reference library on this thermoplastic molding composition. One contains a general description of the properties and uses of the plastic. Another is a 40-page technical handbook on the methods employed in molding Tenite articles. The third gives specific data on the physical properties of Tenite for the formulas and flows regularly supplied.

Mechanical Parts

BALL BEARINGS—Norma-Hoffmann Bearings Corp., Stamford, Conn. Data sheet. Dimensions and other engineering information on diminutive size precision ball bearings with retainers for very small shafts.

BEARINGS—New Departure Division, General Motors Sales Corp., Bristol, Conn., 110 pages, 5½x8½ in. "Why Anti-Friction Bearings", a discussion of the fundamental reasons responsible for the increased use of modern rolling bearings, each chapter separates and highlights some of the more pertinent facts.

BRONZE — Johnson Bronze Co., New Castle, Pa. General Catalog No. 400, 76 pages, 8½x11 in. Over 800 sizes of plain bearings are listed and described with more than 350 listings of bronze bars. Many new numbers added to the electric motor bearing section.

GAS ENGINE—Le Roi Co., Milwaukee, Wis. Bulletin 71, six pages, 8½x11 in. Describes the constructional features and gives full data and specifications on the new model D71 air cooled engine. Two pages of drawings and diagrams show the various power take offs and fuel tanks available.

PILLOW BLOCK—Dodge Mfg. Corp., Mishawaka, Ind. Bulletin A-325, 18 pages, 8½x11 in. Complete information on the new Dodge-Timken double interlock pillow block. In addition the bulletin contains tables for easy selection of bearings to meet any condition of service.

SMALL GASOLINE ENGINES—The Jacobsen Mfg. Co., Racine, Wis. Four-page 8½x11 in. bulletin. Describing the air-cooled gasoline engines of ¾ and 1 hp. manufactured by this company. The folder contains complete specifications for the engines and illustrates some typical applications.

VIBRATION CONTROL—The Korfund Co., Inc., Long Island City, N. Y. Catalog No. Ba. Describing spring suspension of concrete foundations by the use of Korfund Vibro-isolators type U, SP and O including photographs of typical installations and a description of the installation procedure.

Electrical Parts

FANS—Emerson Mfg. Co., St. Louis, Mo. Twenty-three pages, 8½x11 in. Catalog lists nearly 100 types including desk and stand fans, air circulators, ceiling fans, exhaust and ventilating fans. Illustrations, descriptions, detail construction features, performance and list prices are given for all models.

HEATING EQUIPMENT—General Electric Co., Schenectady, N. Y. Four-page bulletin GEA-214D discusses "Calrod" immersion heaters for water and oil. Four-page bulletin GEA-1157C covers strip heaters. Thermostats for use with Midget heating units is the subject of four-page bulletin GEA-1265D. An eight-page bulletin, GEA-2592-A, gives complete information on unit heaters of the forced and natural-convection types. Single page bulletin GEA-104B contains diagrams, specifications and description of catridge-type heating units.

LAMP RECEPTACLE—American Phenolic Corp., Chicago. House Organ, 4 pages, February issue. Details on a new precision receptacle for prefocused lamps used in home and commercial movie projectors, floodlights, searchlights, airplane landing lights. Receptacle is rated at 1000 watts.

MAGNETIC SWITCH—General Electric Co., Schenectady, N. Y. Catalog insert, single sheet GEA-1184D. Description, specifications and features of a-c magnetic motor starting switch CR7006-D30B for squirrel-cage motors or as primary switch for wound-rotors.

MOTORS—General Electric Co., Schenectady, N. Y. Six-page bulletin GEA-1412B covers vertical solid-shaft induction motors. Four-page bulletin GEA-1368D contains information on the construction features and uses of vertical hollow-shaft induction motors. Single page bulletin GEA-3223 gives complete data on type KC single phase vertical motors. Constructional features outlined and completely illustrated.

REVERSING PLANER DRIVE—General Electric Co., Schenectady, N. Y. Bulletin, six pages, 8½x11 in. Contains complete information on variable-voltage reversing planer equipment covering specifically: advantages; complete list of equipment: descriptions and photographs; how the drive operates and how it is rated.

Fabrication Methods

DIE CASTING—New Jersey Zinc Co., 160 Front St., New York, N. Y. Booklet, 35 pages, 6x9 in. Titled, "Designing for Die Casting," this booklet consists of a series of illustrated notes to serve as an aid to design engineers towards economical and more efficient production by die casting. A final page gives full data on the properties of the firm's die cast alloys.

PLASTICS FABRICATION—Carbide & Chemicals Corp., 30 East 42nd St., New York City. Booklet, 18 pages, 8½x11 in. Detailed recommendations on how to machine and fabricate "Vinylite" resins by common woodworking and metal working methods. Best methods of machining, drilling, sawing, tapping and threading, grinding and polishing are given.

SPRINGS, STAMPINGS, ASSEMBLY—Hunter Pressed Steel Co., Lansdale, Pa. Eight-page folder, 4x9 in. Describes types and forms of springs and stampings available and assembly work offered to mechanical and electrical device manufacturers. Photographs of the services available complete the folder.

TUBE FABRICATING EQUIPMENT — Parker Appliance Co., 17325 Euclid Ave., Cleveland, Ohio. Bulletin No. 40E, 34 pages, 8½x11 in. Although major part of bulletin is devoted to tube benders, a page is given over to fabrication of steel tubing and two pages to dual heat transfer coils. Instructions on correct flaring of tubes, flaring tools and fabricating tools complete the bulletin.

WIRE STITCHER—Niagara Falls Wire Stitchers, Inc., Niagara Falls, N. Y. Eight-page folder, 8½x11 in. Features of the machine, its operation and the materials and fields it may be used in are discussed fully in this folder. Illustrations of the machine and its parts make the folder most complete.

Finishes

LUMETRON PHOTO-ELECTRIC COLORIMETER —Photovolt Corp., 10 E. 40th St., New York, N. Y. Six-page 8½ by 11 in. folder. Describing the Colorimeter, a light transmission measuring instrument for comparing the color of liquids and for quantitative chemical analysis.

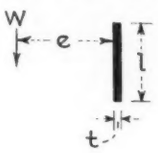
PAINT PROGRESS—The New Jersey Zinc Co., 160 Front St., New York, N. Y. 12-page publication, appearing monthly, containing technical information on various types of flat wall paints, and illustrated by halftones and charts.

Allowable Eccentric Loads on Fillet Welds

E. H. EBERHARDT

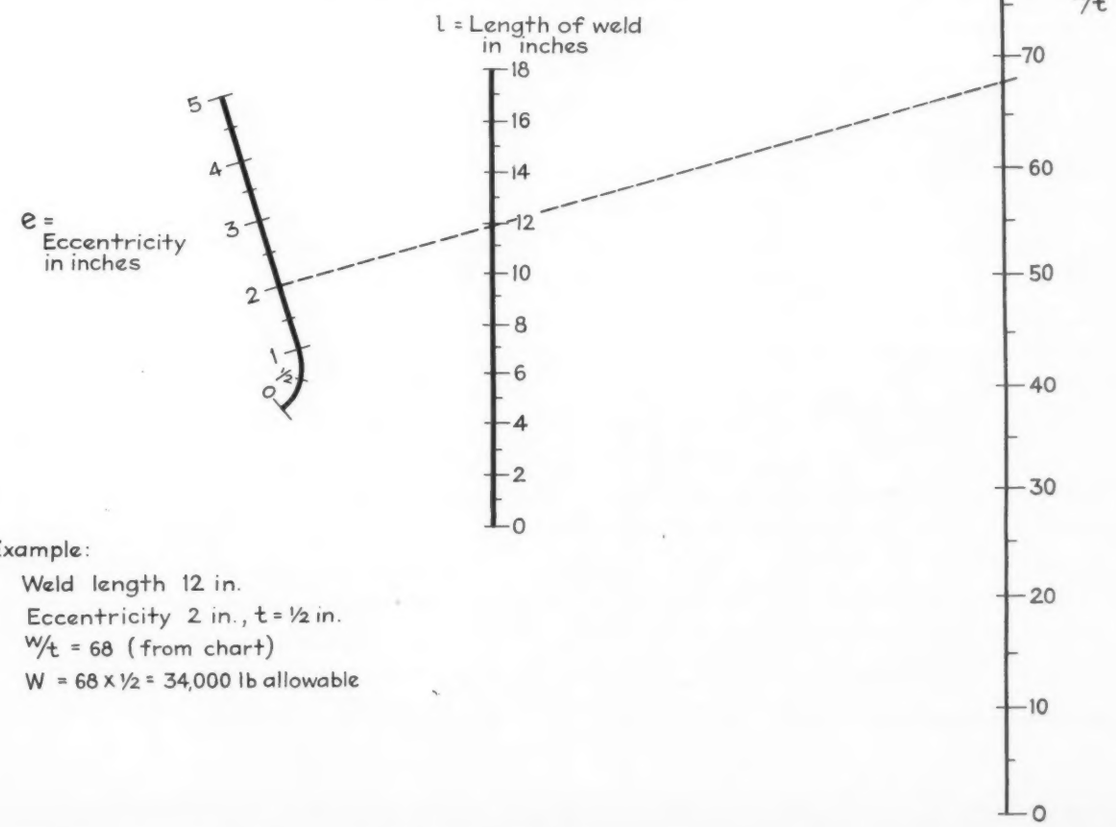
ALLOWABLE ECCENTRIC LONGITUDINAL LOADS ON FILLET WELDS

W = Load in 1,000 lb. = t x chart value
t = Width of weld in.
e = Eccentricity in.



$$W/t = \frac{8l}{\sqrt{1+(6e/l)^2}}$$ A.W.S. code weld stresses

With weld	2 in., max. eccentricity = 3/4 in.
4	1 ½
6	2 ½
8	3
10	3 ½
12	4 ½
14	5



Example:
Weld length 12 in.
Eccentricity 2 in., t = ½ in.
W/t = 68 (from chart)
W = 68 x ½ = 34,000 lb allowable

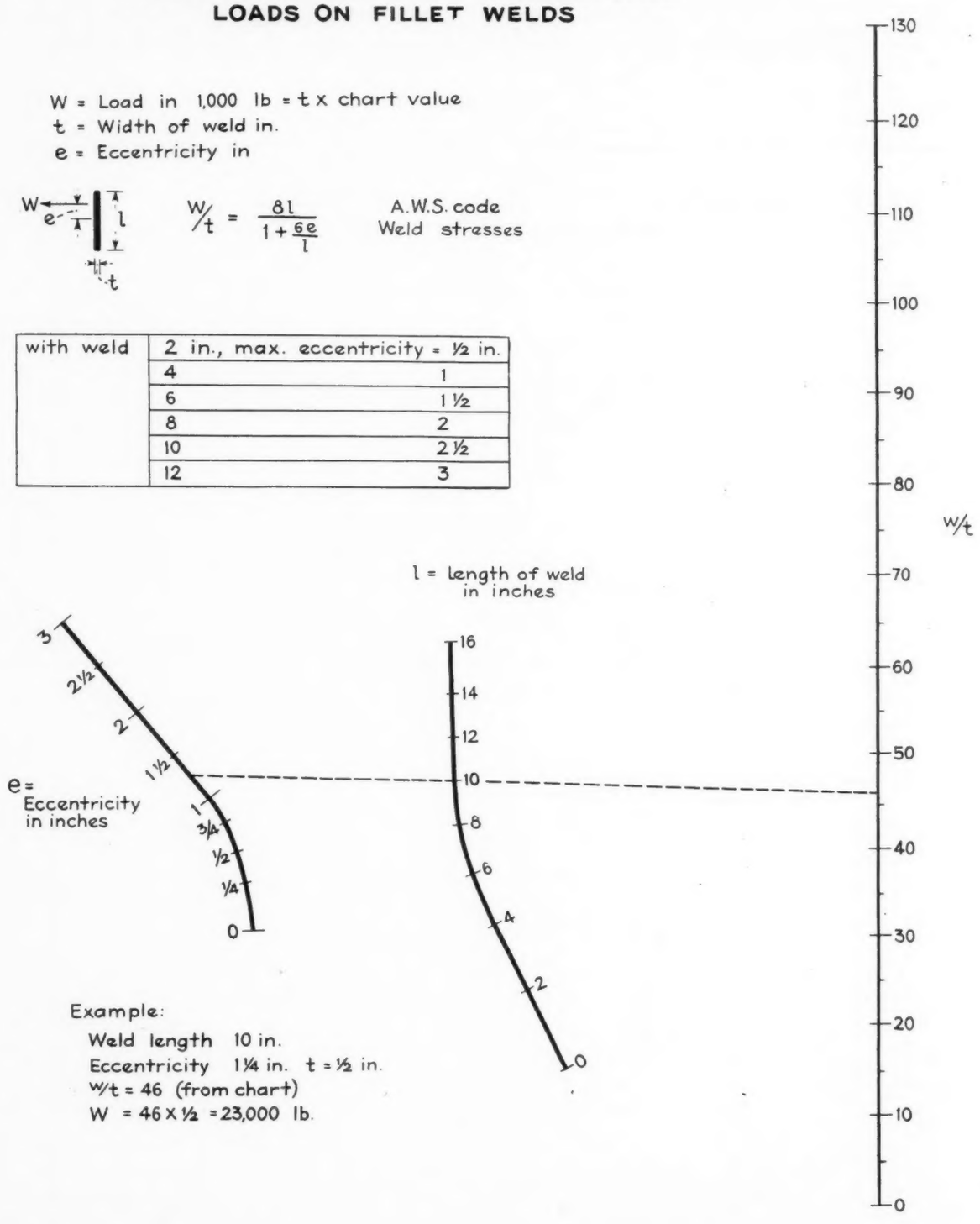
ALLOWABLE ECCENTRIC TRANSVERSE LOADS ON FILLET WELDS

W = Load in 1,000 lb = t x chart value
t = Width of weld in.
e = Eccentricity in

$$W/t = \frac{8l}{1 + \frac{6e}{l}}$$

A.W.S. code
Weld stresses

with weld	2 in., max. eccentricity = ½ in.
4	1
6	1 ½
8	2
10	2 ½
12	3



Example:
Weld length 10 in.
Eccentricity 1¼ in. t = ½ in.
W/t = 46 (from chart)
W = 46 X ½ = 23,000 lb.